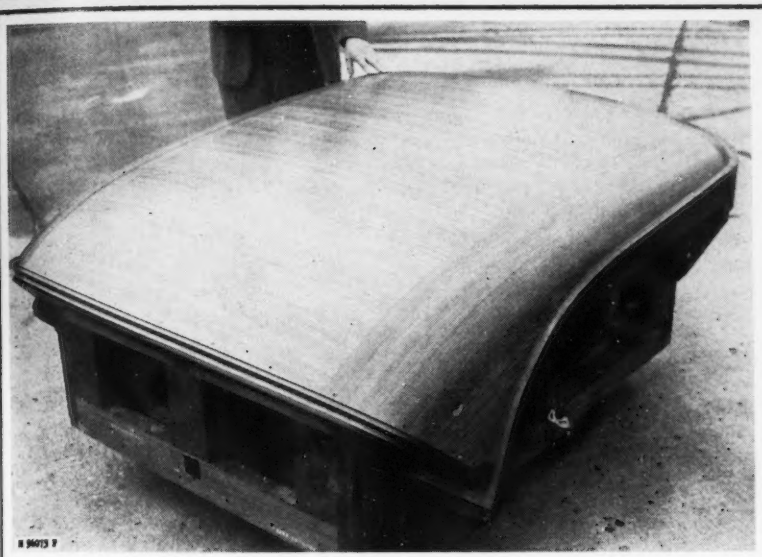
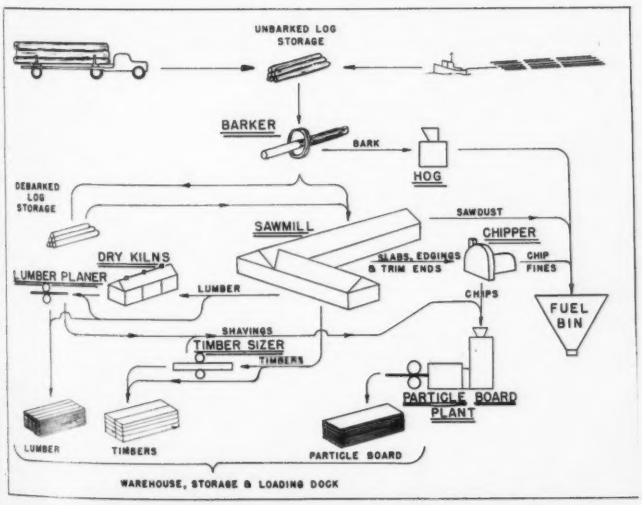
Forest Products Journal

SAN FRANCISCO MEETING PLANS P. 5-A

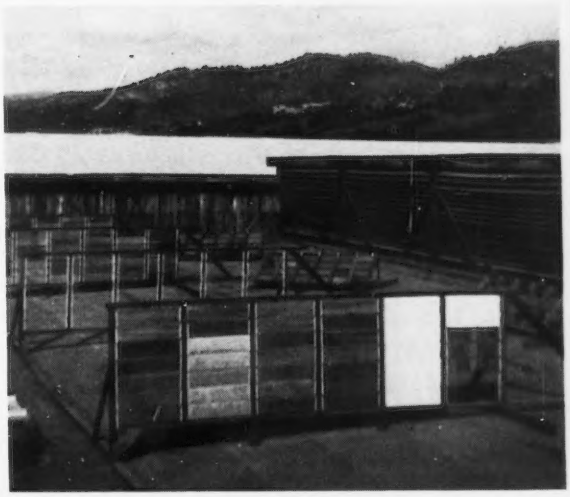


New Approaches to Stabilizing Wood . . . p 107

Router, shaper design . . . p 21-A



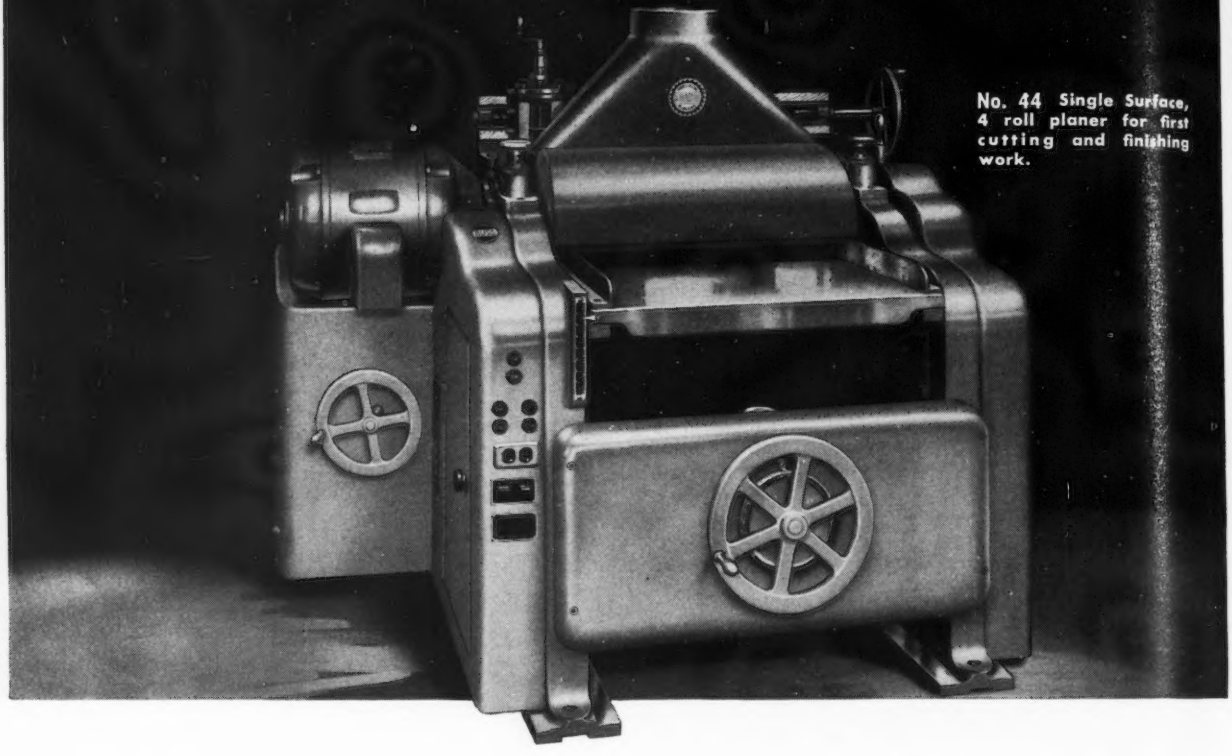
Integrated sawmill -- particle board plant . . . p 15-A



Redwood finishes and the weather . . . p 18-A

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN

Here's why BUSS CABINET SURFACERS ARE UNMATCHED FOR PRECISION PLANING



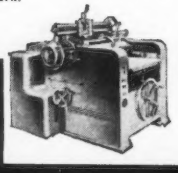
No. 44 Single Surface, 4 roll planer for first cutting and finishing work.

It takes a good mechanic exercising real skill and taking plenty of time for adjustments to produce first class finished planing on the conventional machine. On the other hand, an average operator will *consistently* produce ideal finished planing on a modern BUSS CABINET SURFACER and maintain tolerances as close as .002 an inch with only about one-third the non-productive time for set-ups and adjustments required on other planers. This is due to the fact that in addition to being built throughout for precision planing, BUSS CABINET SURFACERS are equippd with semi-automatic controls (not available on other machines) which make it easy for the operator to get perfect and almost instant settings. For the greatest production of the kind of planing that saves time on following operations, investigate BUSS CABINET SURFACERS. Write for bulletins. Consult us on any planing problem.

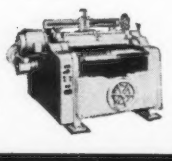
THERE'S A BUSS PLANER TO EXACTLY SUIT YOUR NEEDS

6 MODELS
40 SIZES

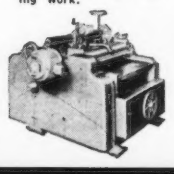
No. 4-L Single Surface, medium sized planer for first cutting and finishing work.



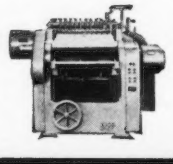
No. 66 Single Surface, 6 roll planer for first cutting and finishing work.



No. 88 Double Surface, 8 roll planer for first cutting and finishing work.



No. 55 Heavy Duty Double Surfacer for planing rough lumber.



MICRO-SURFACER for planing hardboard and other very thin materials.

BUSS
SINCE 1862
MACHINE WORKS

PLANER SPECIALISTS EXCLUSIVELY

292 EIGHTH STREET • HOLLAND, MICHIGAN
A Subsidiary of GREENLEE BROS. & CO., Rockford, Illinois

Executive Officers

President
W. Jeter Eason, Memphis, Tenn.

President-Elect
E. S. Harrar, Durham, N. C.

Vice President
R. H. Berry, Burney, Calif.

Past President
F. H. Kaufert, St. Paul, Minn.

Executive Secretary
Frank J. Rovsek, Madison, Wis.

•

Regional Board Members

Southeast
W. L. Irwin, Pickens, S. C.

South-Central
W. R. Warner, Warren, Ark.

Northeast
D. K. Saunders, Westbrook, Me.

North-Central
J. J. Allegretti, Chicago, Ill.

Northwest
T. S. Veazey, Jr., Butte, Mont.

Southwest
F. E. Dickinson, Richmond, Calif.

•

Publications Committee

Chairman
Edward G. Locke, Madison, Wis.

•

Editorial Staff

Editor
R. H. Hamre, Madison, Wis.

THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin. Second-class postage paid at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

FOREST PRODUCTS JOURNAL

Vol. IX, No. 3 March, 1959

CONTENTS

Page

LUMBER MANUFACTURING

Economics of a Small, Integrated Sawmill—Particle Board Operation.....*M. H. Mater* 15-A
An actual study shows it is economically feasible to produce lumber and particle board at a small plant.

FINISHING

Attempts to Modify the Weathering of Redwood.....*W. A. Dost* 18-A
Most practical solution: let it weather! Otherwise, water-repellent preservatives are best naural finishes so far.

STABILIZING WOOD

Toward New and Better Means of Dimensionally Stabilizing Wood..... 107
Eighty-five top technical men gathered in Madison to exchange ideas and explore new ways to attack this old problem.

Hygroscopicity, Swelling, and Decay Susceptibility of Gamma-Irradiated Ponderosa Pine.....*D. L. Kenega and E. B. Cowling* 112
The Authors present information basic to further work on radiation as a means of carrying out chemical reactions in wood.

WOOD PROPERTIES

Tension Wood in Cottonwood: Its Effects on Density, Toughness, and Compression.....*L. E. Lassen* 116
Cottonwood is of higher quality than most other Midwest species. Increased use depends on more knowledge of its manufacturing problems.

WOOD DRYING

Recommendations of the Madison Conference on Fundamental Research in Wood Drying.....*R. L. Youngs* 121
Seven recommendations are presented on how to increase our knowledge of the fundamental wood-water relationships.

Factors Associated with the Development of Collapse in Aspen During Kiln Drying.....*A. K. Kemp* 124
If conditions that cause collapse in drying lumber are known, then schedules can be modified to avoid its occurrence.

WOOD MACHINING

Design Possibilities of Automatic Shapers and Routers.....*E. Pankonin* 21-A
The problem in machine design is combining function and appearance while reducing the cost of manufacture.

What to Expect in Woodworking Planer Development.....*J. C. Petter* 23-A
Machining and cutting techniques must be improved before real machinery developments are possible.

CHEMICAL UTILIZATION

Alcohol Production from Spent Sulfite Liquor.....*C. A. Watson* 25-A
Though the margin is small, alcohol is an outstanding example of the microbiological utilization of wood.

COMPOSITION BOARD

Developing the Best Resin for the Particular Process.....*C. M. Keaton and R. E. Beyer* 29-A

DEPARTMENTS

FPRS News-Digest..... 5-A
Employment Opportunities..... 12-A
World-Wide Forest Products News..... 31-A
Briefing FPRS Papers
Air Pollution Abatement.....*R. O. Blosser* 33-A
Stream Pollution Control in Wisconsin.....*T. F. Wisniewski* 34-A
White-Pocket Fir for Plywood..... 34-A
Abstracting the Literature..... 35-A
Index to Advertisers.....3rd cover

IMPORTANT FPRS DATES

May 25–26, 1959: Joint Eastern Canadian—Northeast Spring Section Meeting, Ottawa, Ontario.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

Sept. 10–12, 1959: Joint A.S.M.E., A.I.Ch.E., Pacific Northwest—Inland Empire Section Meeting, Portland, Ore.

Oct., 1959: Mid-South Section Meeting, Lufkin, Texas.

Oct. 29–30, 1959: Northeast Section Meeting, Worcester, Mass.

Send A Copy To A Friend

Forest Products Research Society
Box 2010, University Station
Madison 5, Wisconsin

Please send a free copy of FOREST PRODUCTS JOURNAL with my compliments to the persons listed below:

To _____

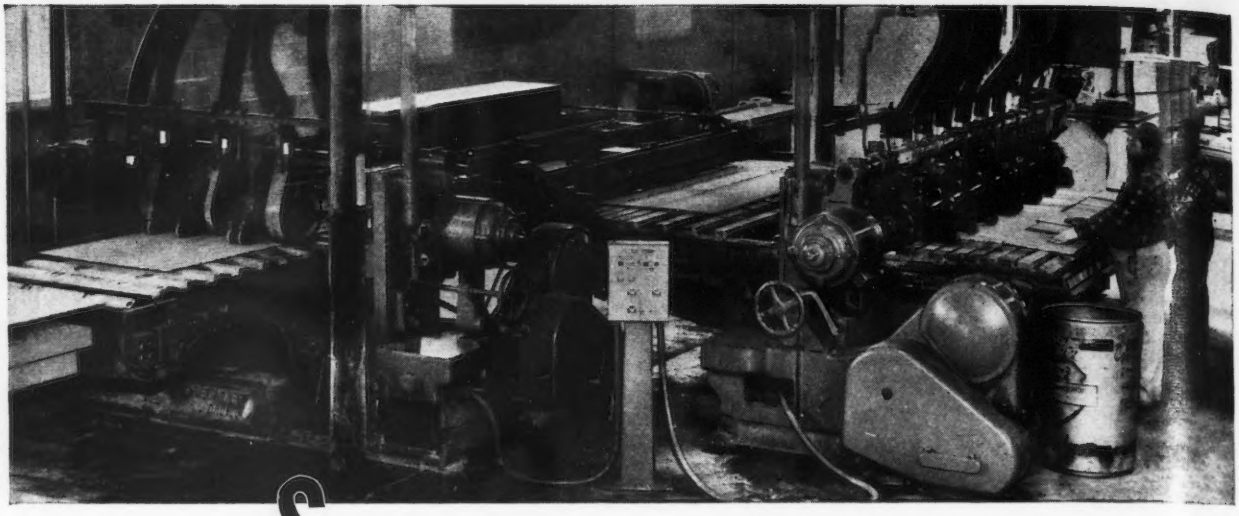
Address _____

City _____ Zone __ State ____

Sender _____

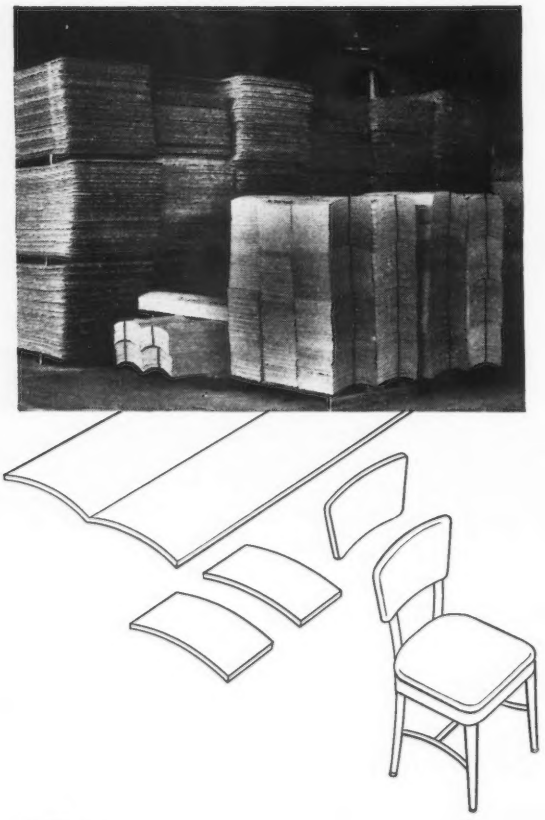
Address _____

_____



SWAIN INDUSTRIES, INC.

CUTS FLAT AND CURVED PARTICLE BOARD



On GREENLEE slat-bed multiple cut-up saws with automatic transfer

Swain Industries, Inc. of Seymour, Indiana had a difficult problem to solve. They needed equipment that would not only cut flat but *curved* sheets of particle board . . . speedily and economically. Representatives of Greenlee and Swain working together in close cooperation came up with the answer.

The Greenlee Cut-Up Saws shown above can take five 37″ x 118″ double curved panels and convert them into 90 accurately cut chair backs in one minute. Flat sheets can be cut even faster.

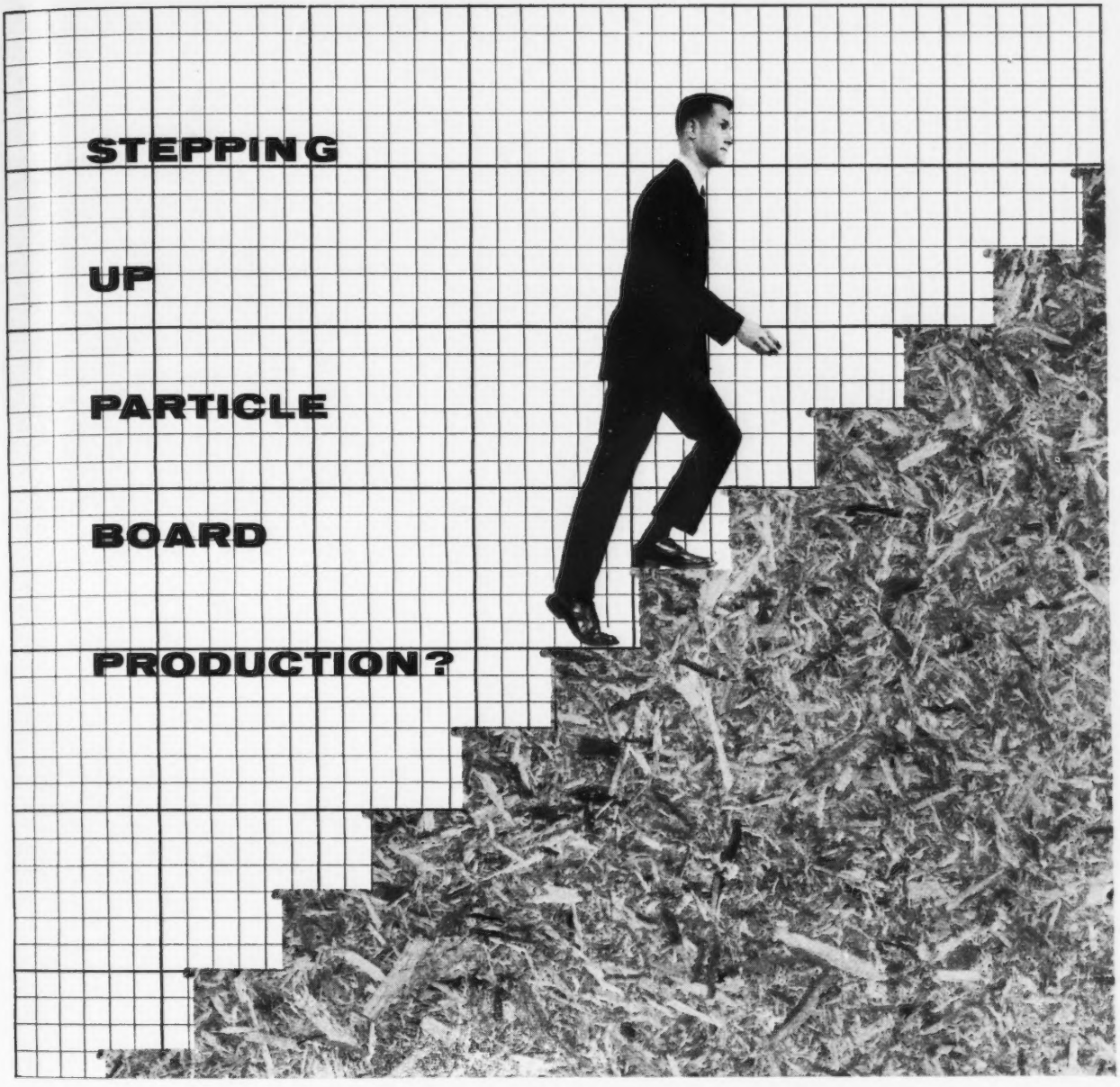
Feed rates are variable up to 110 feet per minute. Set-ups are made easily and quickly . . . can be changed from flat to curved material in a short time. If you have cutting problems involving particle board or any other type of panels, invite Greenlee to help solve them. Write for complete information.

MACHINERY & TOOLS
GREENLEE

WOODWORKING MACHINERY MANUFACTURERS' ASSOCIATION WMMA

GREENLEE BROS. & CO.

1717 TWENTY-FIRST AVE.
ROCKFORD, ILL.



STEP AHEAD WITH *Borden!*

Your step ahead in particle board will be easier and surer with the *right* Borden adhesive. But choosing an adhesive can be tricky . . . and costly. The wood species used, chip shape, moisture, processing equipment, cure cycle, density, and the characteristics you want in particle board must all be considered.

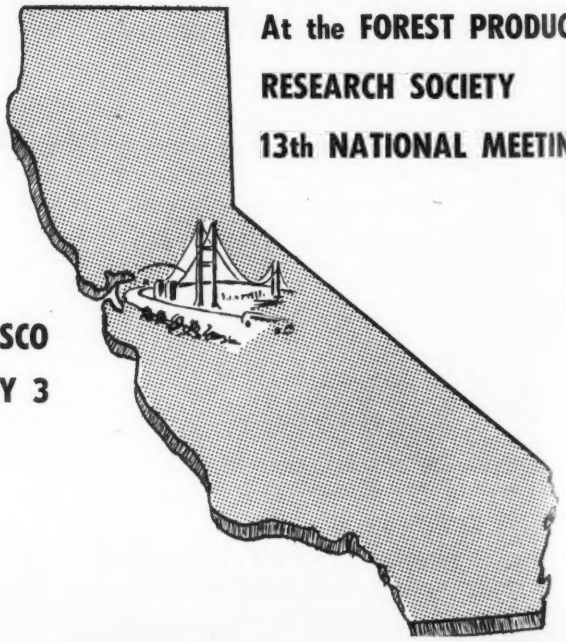
Leading producers rely on Borden—a pioneer in particle board adhesives—to recommend and supply just the right adhesive for fast-stepping, and profitable, production in their plants.

When *you* step up particle board production, specify Borden adhesives. You get Borden production experience, the know-how of Borden wood technologists, chemists, and engineers. And, Borden's complete laboratory testing facilities are always at your service. Make the step ahead with Borden now by writing The Borden Chemical Company, 350 Madison Avenue, New York 17, N. Y.

IF IT'S A *Borden* ©TBC *Chemical* IT'S GOT TO BE GOOD

TRANSFORMING A WASTE MATERIAL . . . Bark . . . into dollars is becoming more and more common in today's wood industry. The 3800-member Forest Products Research Society plays an important role in waste utilization—as it does in every step of wood technology—through the dissemination of the latest information on bark research and bark products.

Turn Waste into Dollars!



At the FOREST PRODUCTS RESEARCH SOCIETY 13th NATIONAL MEETING

In Fabulous SAN FRANCISCO
JUNE 28-JULY 3

Dear Mr. & Mrs. FPRS Member . . .

"This is San Francisco... June 28 thru July 3... and Welcome to it!"

(Reprinted With Appreciation to Herb Caen of the San Francisco Examiner)

This is San Francisco, in all its glorious confusion. You can live here (if you can find a room), but if you die here you can't be buried here (all the cemeteries—like the Cow Palace—are in San Mateo County). There is no telegraph on Telegraph Hill, no mission on Mission St. and no treasures on Treasure Island. The Fairmont, which has seven bars, is owned by a man named Swig, and the two biggest hotels on Powell St. are the St. Francis—named for a saint—and the Sir Francis Drake—named after a pirate.

The Mont Blanc Market, which sounds French, is in Chinatown and owned by Italians, whereas the Italian Market—also in Chinatown—is owned by Chinese. The heart of North Beach, which is not a beach, is Washington Square, which is not a square and which contains a statue of Franklin, not Washington. If a flea bites you, it's because you're a stranger (fleas never bite San

Franciscans, according to accepted legend, because the natives are so full of garlic the fleas can't stand it).

Continued, Page 7a

FPRS News-Digest

Program Rapidly Firming for June Meet

THE LARGEST technical program in FPRS history is nearing completion as the program and Division chairmen of the Society's 14 Divisions report 60–70% confirmation of the papers, authors and presiding chairmen for their sessions.

More than 80 papers and panel discussions will be held, according to general program chairman, E. S. "Scotty" Harrar, Duke University School of Forestry.

Papers and authors for Sessions now 75% or more confirmed include:

VENEER & PLYWOOD

Monday, June 29, 8:45–11:45 a.m.

Potential of Western Hardwoods for Veneer & Plywood. Peter H. Koehler, Timberline, Inc., Crescent City, Cal.

Motion Picture Studies of Veneer-Cutting at the Cellular Level, Lawrence Leney, U. of Missouri, Columbia, Mo.

Lathe Check Formation in Douglas Fir Veneer, E. H. Collins, Weyerhaeuser Timber Co., Longview, Wash.

New Performance Test for Interior Plywood & Application to Panels Containing White Pocket. Robert Ripley, Douglas Fir Plywood Assn., Tacoma, Wash.

Heating Douglas Fir Veneer Bolts—Does It Pay? G. H. Atherton & J. B. Grantham, Ore. Forest Products Research Center, Corvallis, Ore.

LUBKIN

McMILLIN

OEHRLI

WOOD MACHINING

Monday, June 29, 8:45–11:45 a.m.

Presiding Chairman: C. P. Berolzheimer, Calif. Cedar Products Co., Stockton, Cal.

Stresses in Circular Saws. Cecil Best, Calif. Forest Products Lab., Richmond, Cal.

Performance Characteristics of Combination Circular Sawblades on Radial Arm Saws. J. L. Lubkin & C. W. McMillin, American Machine & Foundry Co., Stamford, Conn.

Cross-Cutting Research with Power Chain Saw Teeth. J. W. Oehrli, McCulloch Corp., Los Angeles, Cal.

HANCOCK

BOOTH

HEMMING

GLUES & GLUING

Monday, June 29, 2:00–4:30 p.m.

Elastomeric Adhesives—Their Technology. C. B. Heming & Lawrence Ottinger, U. S. Plywood Corp., Brewster, N. Y.

Elastomeric Adhesives—Their Application in Forest Products Industry. C. C. Booth & C. P. Hancock, Borden Chemical Co., Bainbridge, N. Y.

Finger Jointing at High Moisture Contents. R. A. Currier, Ore. Forest Products Research Center, Corvallis, Ore.

WOOD PRESERVATION

Monday, June 29, 2:00–4:30 p.m.

Presiding Chairman: C. S. Walters, U. of Ill., Urbana, Ill.

Development of Fire-Retardants for Wood Treated with Oil-Type Preservatives. H. M. Tobey, Chapman Chemical Co., Memphis, Tenn.; R. M. Gooch & D. L. Kenaga, Dow Chemical Co., Midland, Mich.

Flame-Spread Measurements on Wood-Base Materials Using Radiant Panel Test Method. Daniel Gross, U.S.D. Commerce, Washington, D. C.

Prevention of Deterioration of Wood in Contact with Iron. J. E. Marian, Calif. Forest Products Lab., Richmond, Cal.

LOGGING

Tuesday, June 30, 9:30–11.30 a.m.

Presiding Chairman: Emanuel Fritz, U. of Calif., Berkeley, Cal.

Small Log Harvesting in Douglas Fir Region. W. A. Davies, Ore. State College, Corvallis, Ore.

Bacterial Attack of Pine Logs in Pond Storage. Eric Ellwood & B. A. Eck-

FPRS Program Shaping-Up for June 28-July 3 Meeting

lund, Calif. Forest Products Lab., Richmond, Cal.
Timber Sale & Logging Contract Writing. Emanuel Fritz, Berkeley, Cal.
Log Supply & Handling Problems in a Northern Calif. Operation. R. C. Andree, U. S. Plywood Corp., Redding, Cal.

WOOD DRYING

Tuesday, June 30, 9:30–12 Noon

Presiding Chairman: Eric Ellwood, Calif. Forest Products Lab., Richmond, Cal.
Shrinkage & Elastic Properties of Ray Tissue as Factors Contributing to Difference Between Radial & Tangential Shrinkage of Calif. Black Oak. A. P. Schniewind, Calif. Forest Products Lab., Berkeley, Cal.
Air Circulation in Forced Air Drying of Lumber. D. M. Post, U. of Fla. Gainesville, Fla.
Solvent Seasoning of Tanoak. A. B. Anderson & W. B. Fearing, U. of Calif., Berkeley, Cal.
Calculating Internal Stresses in Wood. R. L. Youngs & C. B. Norris, Forest Products Lab., Madison, Wis.
Control of Sugar Pine Brown Stain with Sodium Azide. R. E. Stutz, Western Pine Assn., Portland, Ore.

WOOD FINISHING

Tuesday, June 30, 9:30–12 Noon

Presiding Chairman: Don Laughnan, Forest Products Lab., Madison, Wis.
Acrylic Finishes for Exterior Wood Surfaces. Gerould Allyn & James Richardson, Rohm & Haas Co., Philadelphia, Pa.
New Finishes for Wood—Polyester Types. Neil Estrada, Reichhold Chemicals, Inc., San Francisco, Cal.
Development in Color Finishing for Plywood—Precolor Sealing System & Rollgrain Printing. P. E. Leary, Wolverine Finishes Corp., Grand Rapids, Mich.

LUMBER MANUFACTURING

Tuesday, June 30, 2:45–5:15 p.m.

Presiding Chairman: Milton Mater, Mater Engineering Co., Corvallis, Ore.
Place of the Sawmill in an Integrated Forest Operation. L. W. Hooker, Mich. College of Mining & Tech., Houghton, Mich.
Place of the Sawmill in a Predominately Douglas Fir Integrated Forest Operation. D. E. Lane, B. C. Forest Products Ltd., Vancouver, B. C.
Sorting Logs to Improve Sawmilling. H. I. Winer, Yale Univ., New Haven, Conn.
Role of the Sawmill in Whole Log Utilization. N. T. Shelton, Diamond Match Co., Chico, Cal.

PACKAGING

Tuesday, June 30, 2:45–5:15 p.m.

What's New in Pallet Assembly. E. G. Stern, Va. Polytechnic Institute, Blacksburg, Va.
Pallet Bins for Harvesting Apples in Pacific Northwest. S. W. McBirney, USDA, Wenatchee, Wash.
Spiral Wrapping Machine for Panel Products. R. C. McRae, Coast Iron & Machine Wks., Tacoma, Wash.
Engineered Wood Cellulose Cushioning for Packaging. C. E. Swanson, Wood Conversion Co., St. Paul, Minn.

ANDERSON

IVORY

HERSTROM

LUMBER MANUFACTURING & WOOD DRYING

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: Paul Heller, Pacific Pine Co., New Westminster, B. C.
Some Problems in Effectively Using Results of Research in Lumber Manufacturing & Drying. C. F. Anderson, Winton Lumber Co., Minneapolis, Minn.
Segregation of Lumber for Kiln Drying. K. O. Smith, Jr., Cheney Lumber Co., Tacoma, Wash.
Recent Research Results & Their Application in the Lumber Industry. Leif Espenas, Ore. Forest Products Research Center, Corvallis, Ore.
A Sawmill Man Looks at His Own Drying Operation. E. P. Ivory, Ivory Pine Co., Dinuba, Cal.
Automated Sorting & Stacking of Green Lumber in a Small Mill. Charles Herstrom, Powell River Co., Ltd., New Westminster, B. C.

GLUES & GLUING

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: A. A. Marra, U. of Mich., Ann Arbor, Mich.
Responsibility of the Trade Assn. to the Industry. R. C. Raymond, Douglas Fir Plywood Assn., Tacoma, Wash.
Adhesive Manufacturers' Viewpoint. J. M. Hine, Borden Co., Seattle, Wash.
Plywood Manufacturers' Viewpoint. K. K. Graves, Georgia-Pacific Corp., Portland, Ore.
Industry-Supported Testing Lab. Viewpoint. L. A. Patronsky, Timber Engineering Co., Albany, Ore.

INDUSTRY–EDUCATION

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: W. E. Welch, Timber Structures, Inc., Portland, Ore.
Industry's Education Responsibilities. R. H. Gloss, Timber Engineering Co., Washington, D. C.
Architect's Use of Wood. Henry Hill, San Francisco, Cal.
Education Sells Wood Structures—A Company's Experience. G. A. Williams, St. Paul & Tacoma Lumber Co., Tacoma, Wash.
Objectives of NLMA's Education Program. G. F. Prange, NLMA, Washington, D. C.

GENERAL

Thursday, July 2, 9:00–11:30 a.m.

Presiding Chairman: R. A. Cockrell, U. of Calif., Berkeley, Calif.
Process of Converting Sawdust to an Efficient Fertilizer Carrier/Soil Conditioner. Eduard Farber, Washington, D. C.; R. R. Hind, Pope & Talbot, Inc., & Fersolin Corp., San Francisco, Cal.
Merchandising Aspects of "Non Com". R. H. Bescher, Koppers Co., Inc., Pittsburgh, Pa.
Effect of Formation Variables on Properties of Wood Particle Moldings. T. J. Patterson, Georgia-Pacific Corp., Hillsboro, Ore.; & J. D. Snodgrass, Ore. Forest Products Research Center, Corvallis, Ore.
Continuous Carbonization & Briquetting of Wood Residue. E. E. Dargan, Charcoal Industries, Inc., Conway, S. C.; & W. R. Smith, USDA, Asheville, N. C.

WOOD COMPOSITION BOARD

Thursday, July 2, 2:00–4:30 p.m.

Presiding Chairman: A. L. Mottet, International Paper Co., Longview, Wash.
A Great Challenge to the Particle Board Industry—Develop Standards. K. W. Guenther, Pope & Talbot, Inc., Oakridge, Ore.
Bending Strength of Wood Particle Board Under Long Term Loading. Eugene Bryan, Calif. Forest Products Lab., Richmond, Cal.
Stability & Strength of Oak Particle Boards as Influenced by Particle Shape and Inclusion of Wax. Bruce Heebink, Forest Products Lab., Madison, Wis.
Durable Adhesives for Particle Board. John Hine, The Borden Co., Seattle, Wash.

QUALITY CONTROL

Thursday, July 2, 2:00–4:00 p.m.

Presiding Chairman: A. E. Wiley, Mich. State Univ., E. Lansing, Mich.
Methods & Machines for Quality Control of Forest Products. O. J. Black, I. B. M. Corp., New York, N. Y.
Usefulness of Surface Texture Measurements for Quality Control. D. A. Stumbo & J. E. Marian, Calif. Forest Products Lab., Richmond, Cal.

This is San Francisco, Cont'd

The steepest hill in town (37.1 degree grade) is on Filbert—which makes sense: only nuts drive up and down it. A great restaurant (Trader Vic's) is in a glorified shed in an alley; another good restaurant (Blue Fox) is right across the alley from the morgue, and a third (India House) is right around the corner from the coroner. Finocchio, a celebrated joint featuring female impersonators, means "fairy" in Italian—and there's a Penthouse Club (in Trinity Place) that's 'waaay up there on the second floor.

San Francisco Art Tower - from Columbus and Union Streets

August is traditionally one of the coldest months of the year, and the people who live in the Sunset District sometimes don't see the sunset for weeks. There are 48 foghorns around the Bay that blow and blow without disturbing the fog a bit. And a nice day in town is when the men walk with their hats in their hands instead of their hands on their hats.

The strangest baseball games in the country are played on Alcatraz; if a prisoner hits a ball over the fence (and into the Bay) he's automatically out. The San Francisco Yacht Club is across the Bay in Belvedere, and the South End Rowing Club is at the North End of town. The slogan of the Scavengers' Assoc. (the garbage collectors) is "Always At Your Disposal," and a liker store on Market invites you to "Come In and Booze Around." Market St. Van & Storage is on Mission, the Italian-American Society is on Russia Ave., near London St.—and the College of Physicians & Surgeons (on 14th St.) teaches nothing but dentistry.

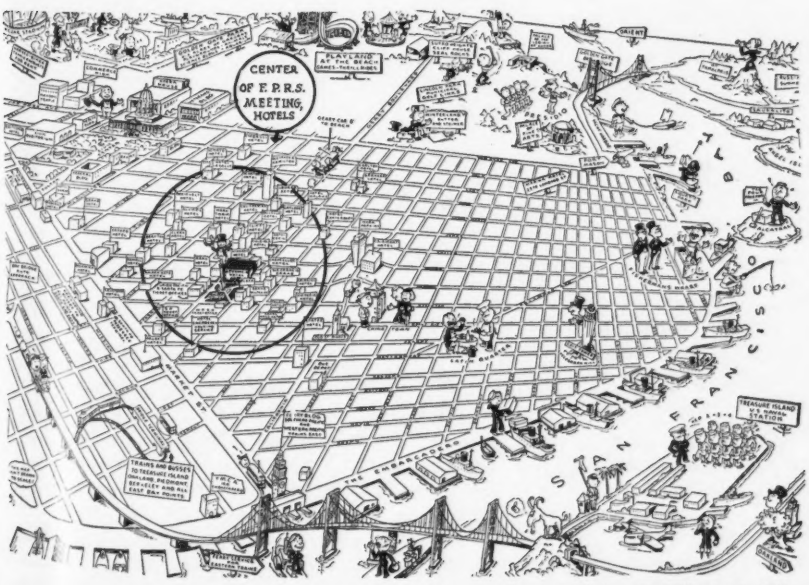
Fly... the Heart

In Union Square, San Francisco

Crazy San Francisco. Everybody warns "Don't call it Frisco," but a bar on Sixth has been calling itself that for years—and getting away with it. The biggest newsstand in town is run by a midget; the highest building in town is owned by a capitalist lawyer who defends Communists, and Harry Bridges, who has given ulcers to many a shipowner, now has an ulcer of his own.

The late Art Hickman wrote his biggest song hit, "Rose Room," at the St. Francis, which has no Rose Room; there is one at the Palace, however. Enrico Banducci, owner of the Hungry I, never takes off his beret because he's sensitive about his bald head; he lost his hair because he never takes his beret off. I Magnin's which caters to fine-feathered females, occupies a building without ledges or cornices—to keep the fine-feathered pigeons from getting a toe-hold.

And *that's* San Francisco, Mr. and Mrs. FPRS. We think you'll like it, because it likes everybody. Even the people who call it Frisco.



—Courtesy Vortex, V. XIX, April 1958

GNAT'S EYE view of San Francisco and principal hotel locations.

BUSINESS TRENDS

Business is generally spotty. In some segments it looks good; in others, hopeful at best. On the whole predictions are for a record year.

Homebuilding. Started off 1959 at annual rate of 1,320,000 starts compared to 1,200,000 in 1958 and 989,000 in 1957.

Commerce Dept. predicts that overall prefabricated housing output will increase 6.6% in '59.

Recent Federal Reserve Board survey shows a "substantial" rise in home buying intentions, 9.3% in '59 compared with 7.5% in '58. Nearly one-fourth of those questioned intend to spend money for improvements or maintenance. The median, $360.

—NLMA Newsletter

Lumber. Production started off this year 5% over a year ago. Softwood production amounted to 2,151,000,000 bf; hardwood, 478,000,000 feet. New orders in January exceeded output by 6%.

Board foot volume of retail lumber in January was 9.2% above a year ago; sales in January was 9.2% above a year ago; stocks, 1.4% higher.

Hardwood Plywood. U. S. output continues to dwindle as imports rise. Production for domestic consumption dropped from 934 million feet in 1955 to 760,000,000 in 1958. During the same period U. S. total consumption increased from 1,553,000,000 to 1,602,000,000 feet a year. In 1958 Japan shipped in 660 million feet or 78% of the total import.

—VENEER Newsletter

Lumber export statistics for 1957 have been released by USDC. Exports totaled 811 million bf, an increase of 5.8% over 1956, but 4% less than in 1955. Softwoods were up 12.7%; hardwoods, down 11.4%.

—U. S. Dept. Comm.

Wooden Pallet Industry experienced a 5% decrease in sales volume during 1958. Sales reached $110,067,000 for third best year in history. Sales increase of 5% is predicted for 1959.

As one step in an expanded promotion effort, the NWPMA plans a 2-day national sales clinic to be held at U. S. Forest Products Lab, Madison, this summer or fall.

—Natl. Wood Pallet Mfgrs. Assn.

Quick Look at Competition. Aluminum industry expects to increase shipments in 1959 from 10 to 15%, resulting in part from development of new uses, particularly in home construction.

Plastics manufacturers predict a 15% increase in use of reinforced plastics for construction in 1959; this on top of a 25% gain reported for '58. According to an industry survey, reinforced-plastic panels will continue to be the major architectural use for several years. Other possible applications —sheathing, plastic surfaces treated to look like wood, reinforced plastic-covered plywood.

—NLMA Newsletter

7-Minute Laminating Process

A recent issue of Armour Research Foundation's news reports development of a new process said to turn out weatherproof, laminated wood beams in only 7 minutes compared with present 4 to 24 hour cycle. Process is credited to Institute of Technology at Washington State College, replaces resorcinol-mixture adhesives and manual clamp bolts with straight phenolic resin and a pre-heat laminating press to accommodate boards up to 2″ x 6″ x 8 ft. Process is said to reduce manpower requirement from 6-to-13 workers to only 3; and cost of adhesives by 6%.

—NLMA Newsletter

Superior Trees, Knotless Lumber Seen for Future

OREGON STATE COLLEGE, CORVALLIS—Vastly improved forests and forest products by the year 2000 were forecast by some 1,000 nation-wide forest leaders who assembled recently at the Oregon State College Forestry Centennial Conference.

Annual timber growth by 2000 will have to be doubled to meet the needs of 100,000,000 more citizens.

Leo A. Isaac said, "artificial cross breeding of strains and species in order to develop in a single tree the superior qualities of two or more parent trees" will be the solution to better trees.

Robert W. Cowlin described present forest research programs as "inadequate." A total of $60 million annually is spent for all forest research. This amounts to only .2 of 1% of consumer expenditures for forest products . . . compared to 1.3% for other industries. Forest research programs should be increased 4 to 5-fold, Cowlin said.

R. W. Hess predicted that "Knots and knot holes will largely disappear in lumber of the future. Boards will be sleek, uniform and clear. The lowest grades will go into fiber products, and use of laminated beams will become widespread in ordinary home construction.

Economic Lift for Beech Lumber

NORTHFIELD, VT.—One of the most neglected trees of the northeast hardwood forests, beech, may be headed for new economic importance, it was revealed by Ronald Gale, wood technologist at the Vermont Bureau of Industrial Research. He pointed out that N. Y. and Vermont have a stand of more than two billion bf of beech—a quarter of the total U. S. growth. Competition from Japan, in the form of American period furniture made from beech, is one of the factors leading to re-appraisal.

U.S.F.P.L.–U. of Wisconsin Graduate Research Program Expanded

Graduate study in forest products providing paid research fellowships and assistantships to candidates for M.S. and Ph.D. degrees will be offered at the U. of Wis. during the academic year starting in Sept. Appointees will do research at the U. S. Forest Products Lab. in cooperation with U. W.

Payments up to $2,000 for the academic year, and opportunity for summer employment will be available, according to Dr. J. A. Hall, director.

Expansion is being made in order to meet growing demands for trained specialists. Assistantships will be available in the fields of civil, mechanical and chemical engineering, chemistry, biochemistry, botany and plant pathology.

COMING EVENTS: SHORT COURSES & CONFERENCES

Quality Control by Statistical Methods. June 9–19, Purdue University, Lafayette, Ind. Simplified approach; practical applications of the methods stressed. Course Director, I. W. Burr. Subjects: Significance tests and confidence intervals. Linear Correlation and Regression. Significance of Differences. Sequential Sampling. Multiple Correlation, and Analysis of Variance. Registration, $150. Write Quality Control Short Course, Memorial Center, Room 110, Purdue U., Lafayette, Ind.

Design of Experiments. June 9–19, Purdue. Course for statisticians, quality control personnel, and others concerned with planning and interpreting results of industrial experiments. Fee, $175. Apply as above.

Statistics Methods for Research Workers. Week of Aug. 10. Brevard College, N. C., sponsored by Inst. Statistics, N. C. State College. Elementary and advance sections will be offered. Fee, $125. Write, Div. College Ext., Box 5125, State College Sta., Raleigh, N. C.

Eastern–Canadian—Northeast Sections to Hold Joint Meet in Ottawa, May 25, 26

One of the FPRS highlights of 1959 will be the joint Section meeting at picturesque Ottawa, coinciding with the famous Tulip Festival on these dates.

The program, under the chairmanship of J. A. Hauter, and J. A. Doyle, deals with the following papers and subjects:

1. Wood as an Architectural Material.
2. Market Research.
4. Particle Board.
5. Millwork Preservatives.
6. Fire-Retardant Treatments for wood.
7. Sonic Method of detecting glue bonds in plywood.
8. Bark as a source of Fiber.

Other features include: Keynote Address by FPRS pres. W. Jeter Eason; conducted tour of the new Ottawa lab. of the Forest Products Labs. of Canada; and the traditional cocktail hour and banquet.

The Ladies' Program will include a tour of Parliament Buildings, boat tour of Ottawa's famous waterways, visit to the Tulip Gardens and other social events.

Meeting headquarters is the renowned Chateau Laurier Hotel. For particulars, write, FPL of Canada, Ottawa.

Pacific Northwest Section Elects New Officers

At its annual meeting, Feb. 2–3, at Coos Bay, Ore., the following were elected to the executive board: Chairman, P. L. Northcott, Forest Products Lab. of Canada, Vancouver; Vice-Chairman, W. R. Francis, Simpson Logging Co., Shelton, Wash.; Secretary, Ed. H. Clarke, U. S. Forest Service, Portland; Treasurer, Don Burnet, Crown-Zellerbach, Camas, Wash.; and Trustee (replacing Alex Fisken) Ed M. Williston, Weyerhaeuser Timber Co., Longview, Wash. Carrying-over on the board, are Past-Chairman, John H. Syme, Edw. Hines Lumber Co., Hood River, Ore.; and W. I. West, Ore. State College, Corvallis, Ore. The perennially favorite Membership Chairman remains Earl T. McCarthy, American-Marietta Co., Seattle.

The site of the 1960 annual meeting will be Bellingham, Wash.

A permanent section Industry-Education Committee was appointed, with W. I. West as chairman, and R. W. Wellwood and H. D. Erickson as members. Its function will be to cooperate with the national FPRS-NLMA Educational Careers program.

SECTIONS *in the NEWS*

Executive Board Meets in Madison, Four Sections Elect New Officers

FOR THE FIRST TIME, the national executive board met in the conference room, known as the "Midwest room," of the new executive office building in Madison, January 20th. All eleven members were present with the exception of W. L. Irwin, Poinsett Lumber Co., and T. S. Veazey, the Anaconda Co. A special guest was E. G. Locke, chairman of the society's publications committee.

Discussions centered about finances, the future course of our publications endeavor, an expanded membership base, progress on issuance of a Guide for Division Officers, and the developing NLMA–FPRS "Careers Unlimited" program for attracting promising young people into the forest products industries. It was noted, also, that with the completion of the office building, the society's assets had increased from $33,000 to a conservatively estimated $73,000. The full report of the 1958 audit will be published in the April Journal.

ON JAN. 19, the day before the board meet in Madison, President Eason, N. Central Region board member Joe Allegretti, and the executive secretary were invited to meet with the Midwest section board members in Chicago.

Shown, l. to r. are Chuck Batten, guest; Dwight Bensend, past Chairman; Pres. Eason; Joe Allegretti; Charlie Walters, trustee; Midwest Section chairman Bill Kluender; vice-chairman, Bob Archambeault; and treasurer, Kenneth Kimball.

FEB. 9, just ahead of our severe snow storms, some 30 students from Iowa State College accompanied by Dean George Hartman, visited our new offices. They had been on their annual trek to the U. S. Forest Products Lab.

SOME 30 MEMBERS and guests of our Rocky Mountain Section met during "Foresters' Days" at Colorado State University, Ft. Collins, on Feb. 20 and 21 to witness the open house of the new Wood Utilization Laboratory, first in Colorado's history. Shown above are, l. to r., newly elected officers, Phil Opsal, sec.–treas.; Linc Mueller, trustee; speaker E. S. Kotok; Harry Troxell, vice-chairman; and Bob Bader, Chairman.

In the adjoining pictures are included some of the speakers—including Gardner Garlick, Protection Products Co., Kalamazoo; University president, Dr. Wm. E. Morgan; Dean C. H. Wasser, and our new section membership chairman, Alan Miller, AFPI, Denver.

Upper Mississippi Valley Adopts New By-laws; Elects Officers

A mail ballot of the 115 members of the Upper Mississippi Valley Section was held recently to approve changes in the Section's By-laws necessary to conform to the national pattern; and elect new officers for 1959.

Approved, 81 to 1, the new By-laws clarify the several offices, establish the fiscal year to conform with the calendar year; specify appointment of nominating committee 60 days prior to, and ballot 30 days prior to, end of fiscal year.

New officers and trustees were elected as follows: Paul H. Lane, Lake States Forest Exp. Sta., Wausau, Chairman; W. L. Meek, M & O Paper Co., Vice-Chairman; L. A. Ropella, Roddis Plywood, Secretary; S. H. Wise, Wood Conversion Co., Treasurer; W. B. Wallin, U. of Minnesota, trustee for 1 year; and H. C. Crandall, Mosinee Paper Mills, trustee for 2 years.

Pacific S'West Holds Successful Meeting, March 11, in Los Angeles

New D.F.P.A. Glue Specifications, and a panel discussion on Particle Board Potential highlighted the early spring meeting of our Southwest section. Bill Ripley, Chairman and Ole Anderson, Sec.-Treas. spearheaded a membership drive which resulted in 4 new members and one possible. The Society appreciates this good work.

Ohio Valley to Meet April 16–17

The spring meeting of the O. V. Section will be held at the American Legion Bonnie Sloan Post, New Albany, Ind.

DIVISION Views and News

ASTM Adhesives Meeting April 28, 29

Sub-committee 10 on Wood Adhesives will meet at the U. of Michigan, April 28 and 29. Arrangements are being handled by Dr. Alan Marra of the Wood Technology Dept. of the University. The meeting is open to anyone interested in the development of better test methods and specs. for wood adhesives.

Hiller to Represent FPRS-S.P.E.

Robert L. Hiller, American Cyanamid Co. and FPRS past-North-Central Region board member has been named by pres. Eason, "liaison representative" from FPRS to work with the Society of Plastic Engineers in areas of mutual interest. In this capacity, Hiller will assist in lining up papers and authors on wood technology for SPE meetings, and assist that organization in presenting papers of interest to FPRS. Other duties will be developed.

ASTM Committee D-7 on Wood Meets

L. J. Markwardt

New ASTM standards and some revisions were proposed at the Annual meeting of Committee D-7 on Wood, held at U. S. Forest Products Lab, Jan. 28–30. A method of conducting machining tests of wood and wood-base materials based on extensive research, will enable wood users to evaluate the machinability of wood, fiberboard, and wood-particle boards. A new standard is also being developed for evaluating wood preservatives by field tests. Methods of preservative treatment of wood, which will be coordinated with AWPA, are prepared.

Changes were made in the standard method of testing glue joints in laminated products for exterior service. Time required for test is reduced from 12 to 8 days.

A progress report was made on the $250,000 wood pole research and testing program. About 44 committee members attended. They voted to again hold their 1960 meeting at the Lab.

Gordon Research Conference on Adhesion. Aug. 31–Sept. 4, at New Hampton School, New Hampton, N. H. Chairman, Alan A. Marra. Purpose is to stimulate research in universities, foundations and industry, achieved through informal meetings consisting of scheduled lectures and discussion groups. Fee of $100 includes registration, room and meals. Write, Dept. Chemistry, U. of Rhode Island, Kingston, R. I.

NAMES in the NEWS

NICKEY

KAUFERT

JAYNE

S. M. (Sam) Nickey Jr. was elected President of the Hardwood Plywood Institute at the association's recent annual meeting in Washington, D. C. Mr. Nickey is Exec. V. P., Nickey Bros. Inc., Memphis, Tenn. Elected as Directors were FPRS members *V. L. Toussaint,* Perry County Plywood, *H. C. Fidler,* Owens-Illinois Plywood, and HPI Managing Director, *Clark E. McDonald.*

F. H. Kaufert, FPRS past-president, and director, U. of Minnesota School of Forestry has been re-elected to his eighth term as President of "Keep Minnesota Green " Inc.

Dr. J. D. Sullivan has been appointed Asst. Professor of Wood Technology at Duke University, School of Forestry, Jan. 1, it was announced by Dean E. S. Harrar. Sullivan, a native of Milwaukee, Wis., received his B.S. at U. of Idaho, 1952; and his Ph.D. from Mich. State in 1958. He has served as a research asst. and Instructor at both schools. A major portion of his past research has had to do with the fatigue characteristics of wood. At Duke he will teach graduate courses in physical and chemical properties of wood.

Dr. Ben A. Jayne, wood technologist who has been on the teaching faculty at Yale, has joined the Institute of Technology at Washington State College, according to George Marra, section head. In his new post, Jayne will direct the new gluing laboratory built to consolidate the Institute's gluing activities. Jayne earned his BS. at U. of Idaho in 1952 and his Ph.D. at Yale in 1955. He is the past secretary of FPRS Northeast Section and the 1955 winner of the national "Wood Award."

W. A. Dost was recently appointed Manager of the Technical and Research Div. of the California Redwood Assn. *Charles Sitterly* was recently promoted to Design Supervisor in the Bilt-Well product development dept. of Caradco, Inc. (formerly Carr, Adams & Collier Co.) Dubuque, Iowa. Chuck has been with Bilt-Well since 1936. *L. N. Ericksen,* California Forest Experiment Station, U. S. Forest Service, has been named Chairman of hotel arrangements, FPRS 13th National Meeting, San Francisco.

"FPRS Salutes"

Men Contributing Time and Effort for Furtherance of the Society and Wood Industry

In few if any types of organizations is "teamwork" more essential than in a not-for-profit technical society such as FPRS.

Among the so-called "unsung heroes" of FPRS are the men (and their ladies) who make possible the outstanding technical program at our national meeting each year. In "FPRS Salutes. . ." this month we would like to acknowledge the work of 4 program chairmen who have been outstanding in the follow-thru and completion of their technical programs for the San Francisco meeting in June. In future months, other men will be recognized.

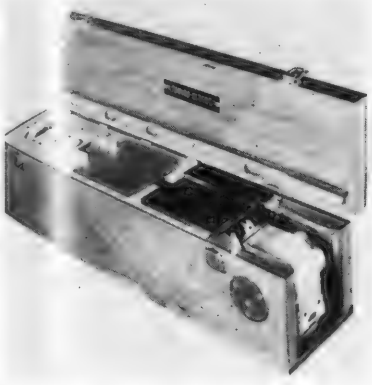
Dr. Ben S. Bryant, vice-chairman of our National Glues & Gluing Division, has lined-up 8 (to date) papers and panel discussions for two sessions on gluing. Assistant professor of forest products at the U. of Washington, Ben has been a member of FPRS since 1950, having that year completed his graduate work at Yale. He has also been a frequent contributor of articles for FPJOURNAL.

Dr. Eric L. Ellwood, vice-chairman of our Wood Drying Division, has completed arrangements for 5 papers in the seasoning session. One of the coming young leaders in this field. Dr. Ellwood received his PhD from Yale in 1953, was the national "Wood Award" winner that year, spent 7 years with the Australian forest products research organization in seasoning and wood preservation, and is currently Chief, Div. of Physics and Mechanics, California Forest Products Lab. You'll meet him in San Francisco.

John F. Lutz, vice-chairman of our Veneer & Plywood Division has nailed-down that div's. technical program for San Francisco. A technologist with the U. S. Forest Products Lab., Madison, Lutz joined FPRS in 1948, while studying for his M.F. at Yale. He received his B.S. at Penn State in 1942, and has been a contributor to the JOURNAL.

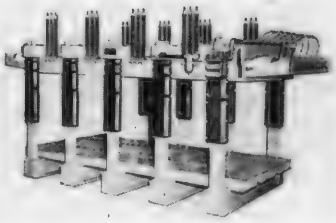
Harvey Smith, of the California Forest and Range Experiment Station, Berkeley, has been doing a yeoman job ever since he joined FPRS as a charter member back in Sept. of 1947. This year, for example, he is doubling as co-program chairman for the joint Lumber Mfg.–Wood Drying session, and is also serving as Chairman of the Committee on Arrangements for the San Francisco meeting. A native of South Dakota, Harvey received his MSF from the U. of Michigan, and has been with the U. S. Forest Service since 1935. He has served as secretary of our N. California section, and is active in the Dry Kiln Club movement. He has authored numerous publications, mostly on the drying of wood.

NEW PRODUCTS and Literature



Adhesives Tester

A new Thwing-Albert T-A-C Tester predicts the production performance of water and solvent based adhesives and rewettable adhesives by putting adhesives and adherents under simulated production in the lab. The tester works on the principle of bonding two surfaces and measuring its strength by its resistance to shear or peel forces. Applicable to paper, board, plastics, wood, etc. Write, Thwing-Albert, Penn St. & Pulaski, Philadelphia, 44, Pa.

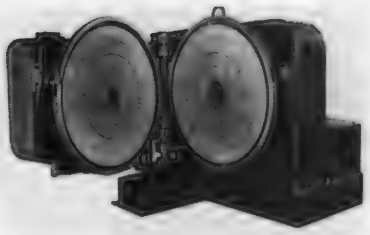


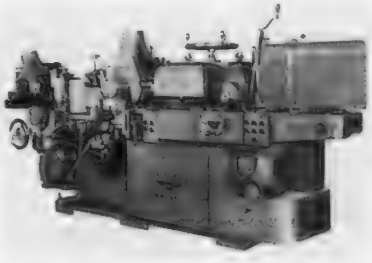
Black Bros. Air Hose Press

Adjustable vertical daylight openings accomplished by means of split sectional spacers, increase the versatility of these laminating presses. The movable spacers allow the top platen of the press to be raised or lowered manually to vary the daylight opening. This allows the opening to be matched to the height of the load, pressing time, etc. for the particular operation. Openings are 4″ to 49″, with larger available. Write, Black Bros. Co., Inc., Mendota, Ill.

New Hardwoods Pulping System

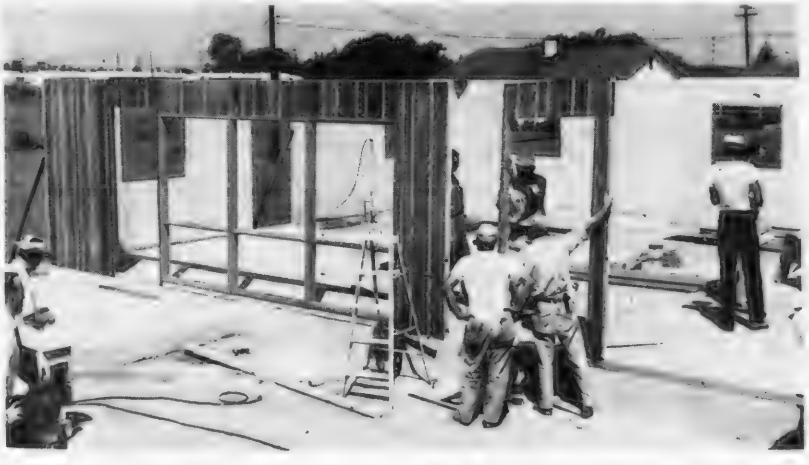
Test runs have been completed on a new cold soda pulping system by the Black-Clawson Co. The system uses a new screw press, reactor, and refiner to produce high quality pulp from hardwoods. When a low chemical concentration is used, the system produces a groundwood type pulp with high opacity. The Chemifiner, pictured, is a double disc refiner that operates at unusually low hp to fiberize the treated chips. Write, Pandia Div., Black-Clawson, Hamilton, O.





Dependable 5th Moulding Head

A fifth moulding head, with interchangeable cartridge unit, is being made by Dependable Machine Co., for use with the firm's Electro-Unit Drive Master Moulder No. 500 series. The unit will take up to a 6 inch head and is available in standard widths of 4, 6, 8, and 10 inches, with the fifth head capable of a 6½ inch cutting circle and maximum knife projection of 1 inch. The fifth head can be used as a second inside head on any angle from 0° to 90°, and as a second top head, the firm reports. Write, Dependable Machine Co., Greensboro, North Carolina.



New Modular Panels

Modular panels featuring both interior and exterior finishes molded to a foamed polystyrene core have been developed by the Koppers Co., it was announced recently. A test house was built with these panels at South Bend, Ind., by the National Association of Home Builders.

Decorative skins or facing material can be molded to the panel core. In the test house, exterior facing was Simpson Redwood Siding and plywood under certain window panels. A variety of facing materials was used for the interior, including plywood, Philippine mahogany, Masonite, and Gypsum board. Roof panels were faced on the exterior with plywood and on the interior with Crezon-faced Douglas-fir plywood.

Panel strength reportedly exceeds specifications established by FHA for load-bearing panels of conventional construction. Largest of the panels used were for the roof, 4 feet wide, 18 feet long, and 4 inches thick. Each of these panels weighed 190 pounds, and was handled by two men.

Pneumatic Steelstrapper

A new way to bundle veneer flitches, or lumber, etc., developed by Acme Steel is shown here. At Hartzell Ind., Piqua, Ohio, the fully-powered A4 Steelstrapper enables two men to bundle from 10 to 11 flitches per hour, including stacking, strapping, tallying and labeling. They report savings in labor costs of about four man hours per day. Write, Acme Steel Co., 135th and Perry, Chicago, 27.

What's New in *Technical Publications*

The following publications are available free of charge from the U. S. Forest Products Laboratory, Madison, Wis.

Hardwood Pallet Manufacturing. T. B. Heebink and E. W. Fobes. Results of surveys made by USFPL and Forest Experiment Stations to determine the types of pallets produced and the materials, methods and equipment used in the hardwood region. Report No. 2132.

Evaluation of Wood Decay in Experimental Work. Carl Hartley. An analysis of existing literature on the amount and consistency of the effects of fungi on different properties of wood. Purpose is to aid in determining which property can best be measured to recognize or evaluate decay in inoculated specimens in trials of preservative treatments or in experiments on the natural decay resistance of different wood species. Report No. 2119.

Adequacy of Light Frame-Wall Construction. R. F. Luxford and W. E. Bonser. November 1958. Results of tests on light frame-wall construction, braced and unbraced, and involving several types of sheathing, size, and spacing of studs. The wall panels were tested for resistance to such racking and static-bending loads as might be imposed on the wall of a house due to wind. Report No. 2137.

(advertisements)

WILCO REFUSE BURNER

Three Models. Complete Range of Sizes. Lowest-cost installation. Prefabricated, one-piece panels. Exclusive triple-draft. Sizing engineers available to you.

WILCO MACHINE WORKS, INC.
Municipal Airport • Memphis, Tenn.
P. O. Box 3722 • WHitehall 8-4555

One Car 6-foot New KD Oak Stacking Sticks

6¢ ea
f.o.b. Mill

S2S 15/16

GAIENNIE
Wholesale Lumber Co.
BOX 1774, SHREVEPORT, LA.

EMPLOYMENT *Opportunities*

FPRS Employment Service is operated without charge to members. Organizations having positions to be filled; or persons seeking employment may insert a free listing in two consecutive issues. Inquiries concerning listings, or information should be addressed to: FPRS Employment Service, 417 N. Walnut St., Madison 5, Wis. All correspondence is kept strictly confidential.

Positions Offered

E–333—Sales rep. for hardwood and softwood concentration yard in N. Y. area.

E–334—Adhesives research supervisor. Must have BS in chem. eng. or chemistry. Some research and adhesives or gluing exp. necessary.

E–335—Glue dept. mgr. Resp. for production of resin and protein glues, administration of sales, and technical services to firm's plywood and door plants. B. S. Chem. required.

E–336—Technical director to formulate and administer product development for lumber, plywood, door, acoustical tile, and insulating board divisions. Advance degree and heavy experience required.

E–337—Wood tech. for engineering dept. of organ co. in Chicago. Investigate new methods and materials for quality woodwork.

E–339—Two product development engineers. Aggressive men, 25–45, with knowledge of window frames, hardware, sash to develop new ideas. Some knowledge plastics. Design background essential. Exp. in millwork beneficial. Salary in line with exp. (Apr.)

E–341—Director of urea adhesives lab. Senior chemist in charge of resin and hardener formulation, product development, customer application and plant control. In East. (Apr.)

E–342—Adhesives technical service rep. Opportunity for man with experience in plywood and particle board applications. East. (Apr.)

E–343—San Francisco lumber and wood products wholesaler seeks forest products grad. interested in sales career. (Apr.)

E–344—Wood techn. for lab. work on plywood gluing problems. Knowledge of plywood, glues gluing practice required. Work under supervision but be able to carry-out projects and write reports. Pac. Northwest. (Apr.)

E–346—Midwest adhesives co. seeks wood techn. or allied exp. for laboratory technical work. Can lead to tech. representative. (Apr.)

Employment Wanted

No. 513—Graduate with MS in wood technology available for employment in wood products industries early June. Prefers western states. (Mar.)

No. 516—Graduate from U. of Washington with BS in forestry available for employment August, 1959. Major was forest products with courses in quality control and wood utilization. Currently officer in U. S. Marine Corps. (Mar.)

No. 522—Graduate in Timber Management, forest engineering and utilization wants research position in by-product or waste utilization. (Mar.)

No. 523—Graduate with B. S. in wood technology desires position in forest products sales. University training in sales and wood engineering fundamentals. Experienced in retail and wholesale lumber sales. (Mar.)

No. 529—Graduate with B. S. in wood technology desires position in wood products industries. Age 27. Background includes wood properties, wood chemistry, pulp and paper chemistry, and statistics. Available June. (Mar.)

No. 532—Graduate with B. S. in industrial education with minors in mathematics, wood utilization, and physical science desires employment in wood utilization industry starting in June. (Mar.)

No. 479—Technical or production position desired. Age 32. Holds a B. S. in Wood Technology and degree in forest engineering from German technical university. Has experience as plant superintendent. (Mar.)

No. 534—Dry kiln operator or tender. Anywhere in U. S. Mature person. Now in Calif. (Apr.)

No. 535—Yale June grad, Dr. of Forestry, age 28, married. Avail. Aug. 1 for basic research in wood physics or mechanics; or advanced products development. (Apr.)

No. 536—Yale school Forestry, about to graduate. Desires management or research position in composition board, plywood or laminating industry. Age 26; married. (Apr.)

No. 537—Wood preservation engineer. Exp. in research and product development. M.S. wood techn. 1957 (Apr.)

No. 539—May graduate, B.S. forest products, Iowa State. Desires position in product development or quality control. Age 27. Prefer midwest or west. (Apr.)

No. 540—June grad with B.A. in Economics, MS in Wood Techn., U. of Michigan, seeks position in furniture production. (Apr.)

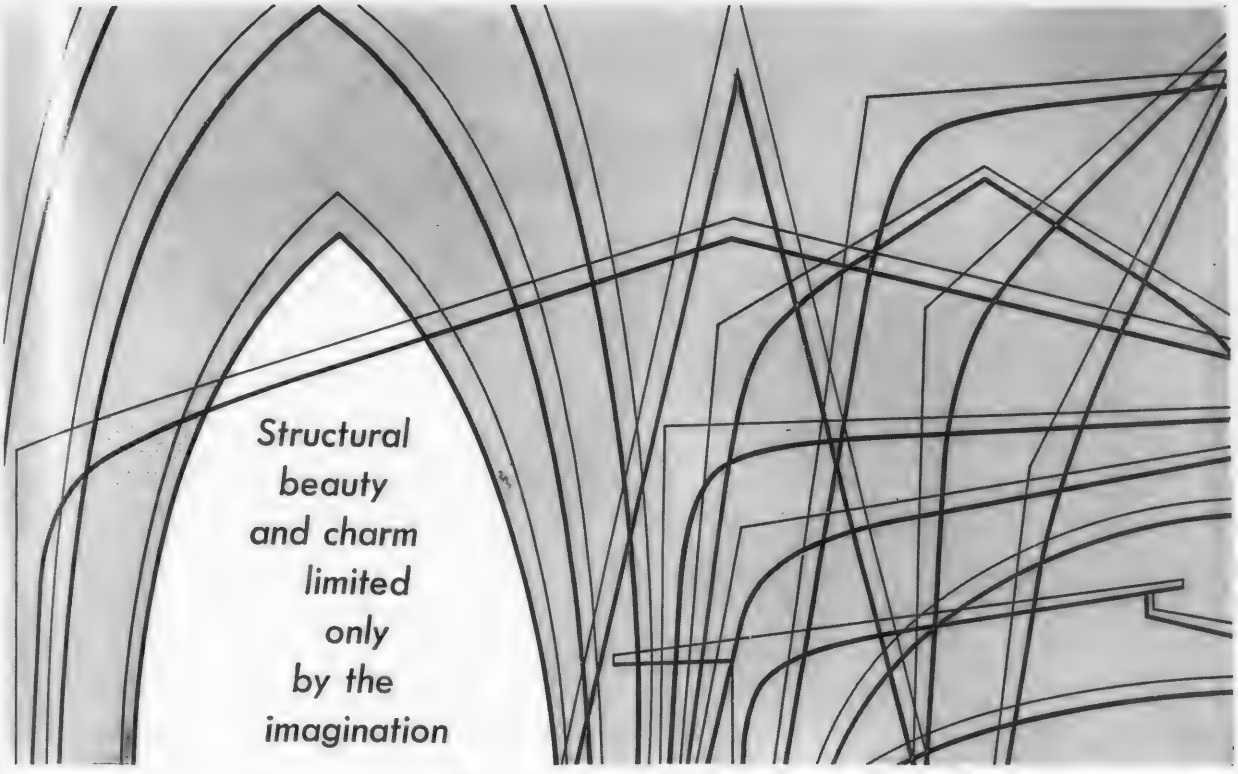
No. 318—West coast wood technologist, age 43, married, seeks challenging opportunity. B.S. forest products, U. Washington; 6 years leading research lab. as seasoning researcher; plywood experience. (Apr.)

WANTED MANAGER

Wood technologist with practical experience in production to manage modern wood working plant in East Tennessee. Applicant must have had several years practical experience in the direction of production and he must be able to assume responsibility so as to take complete charge of the operation. Because plant is highly mechanized, the ability to see that equipment is properly maintained is important. Salary and bonus in high four figure bracket. This is a good opportunity for a competent person.

Send replies to:

E-340, Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
417 North Walnut Street
Madison 5, Wisconsin



PENACOLITE® Adhesive laminated timbers permit extensive freedom of design . . . economically

Wooden arches, beams and trusses laminated with waterproof PENACOLITE resorcinol adhesives — for bonds stronger than the wood itself—offer the designer full freedom of expression. These glues allow wooden members to be easily shaped to any desired form in either traditional or contemporary design with many combinations and variations of the basic types . . . without losing inherent structural strength.

Economy of Laminated Wood Construction

Laminated wood is one of the most economical types of construction. It arrives at the job site already fabricated and cut to size for fast erection—resulting in reduced construction costs. In addition, laminated timbers with their natural color and beauty eliminate the need for costly concealing finishes.

PENACOLITE adhesives will retain their strength even under the most exacting temperatures, ranging from —40°C. to temperatures that char the wood—earning for laminated members favorable fire insurance rates.

Room Temperature Curing with PENACOLITE Adhesives

PENACOLITE adhesives are thermo-setting resins that cure easily at room temperature (70°F.). The curing process is irreversible—glues cannot be softened by further heating.

Write for the PENACOLITE Adhesives brochure, C-6-149, Koppers Company, Inc., Chemicals and Dyestuffs Division, Pittsburgh 19, Pennsylvania.

KOPPERS®

Photo, Unit Structures, Inc.

Carnegel Theater, University of Tennessee—Penacolite adhesives bond these exposed timbers. Building octagon shaped. Arches—"V" type span—60'.

Photo, Unit Structures, Inc.

Church in Conover, N.C.- Bonding adhesives—Penacolite. Arch span varies from 37'3" to 97'10". Roof pitch varies per foot from 34-27/32" at one end to 4-5/8" at the other.

Photo, Unit Structures, Inc.

Dierks Forest Company Office Building, Hot Springs, Arkansas—Penacolite adhesives were used in this modern office building in laminated timbers.

10 times higher

than the Eiffel-Tower

would be a massive column of

particle boards

on a surface of 11 square feet,

resulting from the

daily output

of the production machines

we now have under construction.

A testimony of confidence of

our customers.

A testimony of the great efficiency

of our company.

Siempelkamp

G. Siempelkamp & Co.

Maschinenfabrik · Krefeld · Western German

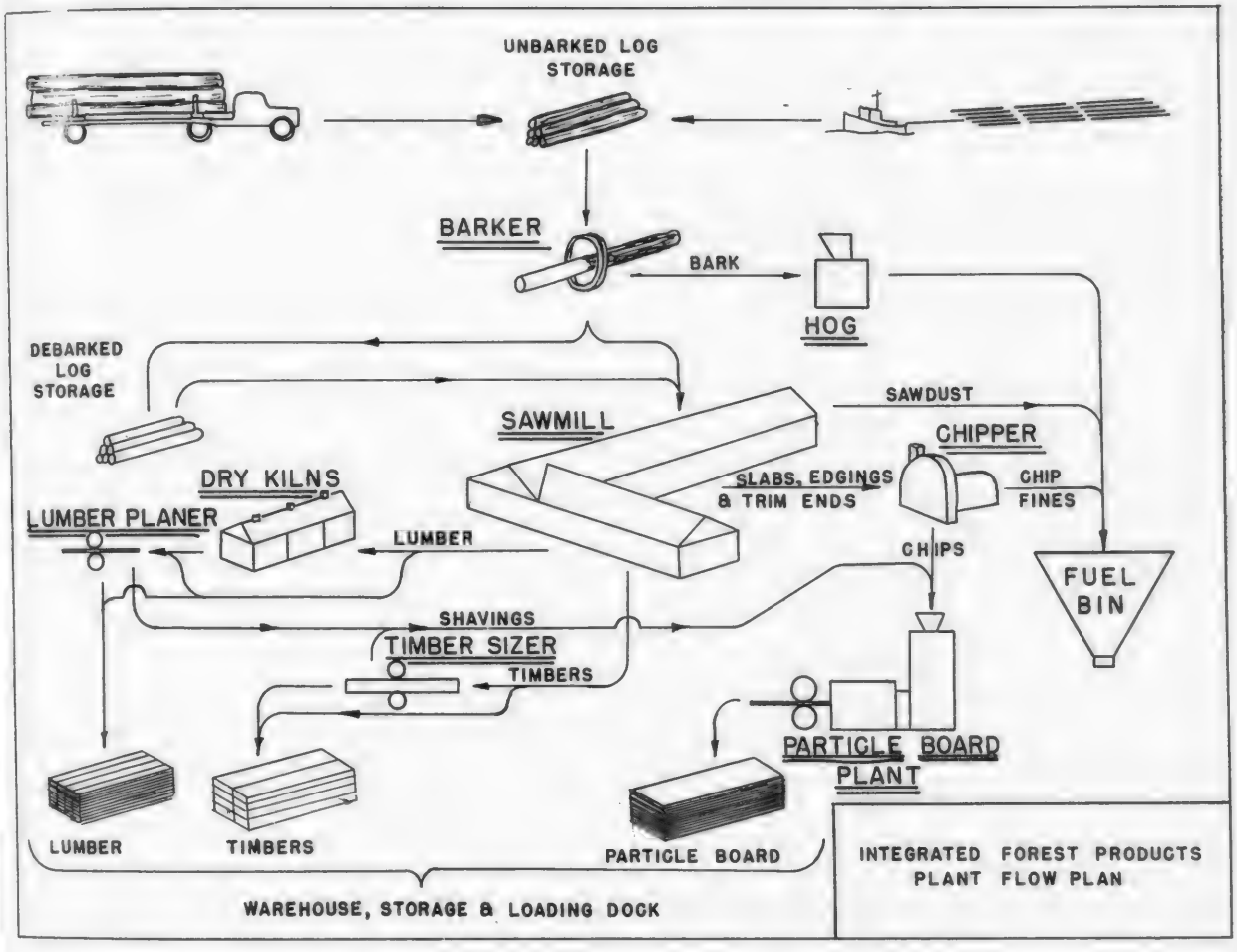
Cable: Siempelkampco · Telex No.: 085 3811

Telephone: 2 86 76

FPRS FOREST PRODUCTS JOURNAL VOL. IX, NO. 3 MARCH, 1959

ECONOMICS OF A SMALL, INTEGRATED

Sawmill—Particle Board Operation[1, 2]



M. H. MATER
Mater Engineering, Corvallis, Ore.

The Author: Milton Mater, licensed mechanical engineer, is head of Mater Engineering, sawmill consulting engineers, and Mater Machine Works, sawmill machinery manufacturers.

Complete log utilization to produce lumber and particle board has been limited to very large plants. Modern machinery and technology make small plants economically feasible without huge capital investment and timber resources. The small plant can operate very efficiently.

FOREST PRODUCTS REDUCTION PLANTS that are integrated in the sense that they utilize the residue from the sawmill to manufacture particle board or other saleable material, have usually been large multi-million dollar complexes with enormous timber resources. This paper is taken from a feasibility study and prospectus prepared for a Western Canadian firm, which owns modest timber resources and can support only a 40,000-board-foot-per-shift sawmill and auxiliary plants.

Such a plant, built in accordance with the latest technological advances in forest products reduction, is feasible and affords an excellent return on the investment dollar.

By definition, an integrated forest products plant is one that manufactures the highest quality and highest production of lumber from its available log

[1] Presented at the Pacific Northwest Section Meeting, FPRS, May 5-6, 1958, Seattle, Wash.
[2] This paper is derived from an engineering prospectus prepared for the Mayo Lumber Co., Ltd., Duncan, B.C., Canada, and is presented with their permission.

supply, and also makes useful and saleable products from the residue of its own sawmill. The connotation attached to this type of plant, however, is much broader than the bare definition. An integrated plant is modern, efficient, and self-contained; it is a factory that receives logs as a raw material, converts them to lumber and other useable products, and delivers these products to the warehouse in a ready-to-sell or ready-to-use condition.

Economic Basis of the Small Integrated Plant

The economics of this type of plant, as compared with an old-fashioned sawmill that produced only green lumber and burned its waste products, explain the advantages immediately:

First: In the old-fashioned sawmill, 50 per cent of the log, by volume, is burned as waste. In an integrated mill, all this waste is processed and converted into saleable material. Thus, if a log is worth $100 (at a going rate of $50/M bd. ft.) delivered at either the sawmill or the integrated plant, the sawmill will burn $50 worth. The integrated plant will process and sell $100 worth of logs. $2,000 worth of logs are processed per shift in a mill sawing 40,000 board feet per day, the initial economic advantage of the integrated plant is immediately apparent. Instead of burning $1,000 worth of the incoming material, as is done in an old-fashioned sawmill, the integrated plant processes and makes saleable the complete $2,000 worth.

Second: The integrated plant is a complete plant within itself. Some of the lumber from the sawmill can be dried in dry kilns, thereby raising the selling price and aiding in the capture of a larger portion of the lumber market. If lumber can be planed, either green as it comes from the sawmill, or dry as it comes from the kilns, the selling price will again be raised. The plant will also be able to fill orders that otherwise might be lost. If dry planed lumber brings $20 per thousand more than green rough lumber, it becomes apparent that if 50,000 board feet were dried and planed each week, the integrated plant would have $1,000 greater return on its product than a basic sawmill alone.

Third: An integrated plant applies to its processing the latest developments of modern technology. Process flow lines are established as in any industrial plant, such as a steel or aluminum reduction and processing plant, and automatic machinery is used, which makes maximum use of minimum manpower. Sawmills that use 11 men to produce 40,000 board feet of lumber per shift can no longer make a product competitive with other building materials. The modern sawmill can use four men for this size mill. The difference in direct labor cost is about $4.00 per thousand, if we assume a labor cost of approximately $6.30 per thousand in the old type mill and $2.30 per thousand in the new mill. In a 40,000 bd. ft. mill, this amounts to a cost reduction of $160 per shift, or $32,000 in a year of 200 days.

The particle board plant, which is a part of the integrated plant, also uses comparatively few men per shift to process the residue material from the sawmill.

Fourth: The integrated plant is designed for efficient flow of materials through the plants and into the warehouse. Warehousing is a large part of the cost of any industry, but it is higher in the sawmill because it is not usually planned as part of the sawmill. In the integrated plant, the warehousing, shipping, and sales are an integral part of the operation, so that inventory, storage, and loading in and out can be as efficient as in other industries.

Automation is Bringing the Coal Within Reach

The integrated plant has been the goal of the forest products industry since the early days of the pulp and paper industry. Much progress was made in this direction by the large operators between World War I and World War II. The great breakthrough in automation technology made during World War II now permit smaller automated plants to be built as compact, economic units. Because of their comparatively low fixed investment and the small timber holdings required to keep them operating on a perpetual-yield basis, these small integrated plants are flexible enough to conform with the vagaries of the construction industry. Many forward-looking thinkers in the forest products field believe that this size plant is the plant of the future, the plant that will survive when larger and smaller plants and all un-integrated plants can no longer operate economically.

Raw Material Economic Base

Timber forms the economic basis of any forest products enterprise. Since amortization on machinery is taken in 10 years, and 20 years on buildings, the timber supply should be assured for at least 10 years before building a plant of this type. While it was expected that logs could be purchased for this particular operation, the timber owned by the company was taken into basic consideration. It was found that, on the basis of a conservative growth figure of 4 per cent of natural increase a year, the timber owned outright would more than supply the requirements of this operation for its amortization life.

Process Flow and Physical Facilities

In this particular integrated plant process, there are two major producing units—the sawmill and the particle board plant. On the efficiency of these units depends the over-all quality and quantity of the products. In the integrated plant, however, every part of the process is essential to the operation of the whole. The sawmill cannot produce if logs are not fed efficiently to it and lumber withdrawn efficiently from it. The particle board plant cannot produce if logs are not debarked and chipped. The entire plan is based on the interrelation between all facilities.

The basic flow for the conversion of the raw materials to useful and saleable items is (Fig. 1):

1) Logs are received either from water-borne rafts or from trucks, and are stored in log decks on dry land. These log decks are segregated according to species and size for purposes of inventory control and ease of selection.

Table 1.—ESTIMATED ANNUAL OPERATING COSTS & PROFIT PER $100 OF SALES[1]

	Sawmill, 1 Shift $	Particle Board Plant, 2 Shift $
Raw Materials		
Logs delivered to mill	55.20	...
Log handling	3.30	...
Chips for board	-----	5.15
Resin and size	-----	17.40
Utilities		
Electricity	.89	2.03
Oil	-----	3.25
Water and sewage	.05	.04
Labor		
Direct labor	5.32	3.18
Direct supervision	0.54	1.96
Yarding costs	0.52	...
Yarding labor	0.54	...
Pay roll overhead	-----	.44
Investment		
General overhead	3.80	1.86
2% plant investment	0.76	.55
Maintenance	1.52	1.68
Operating supplies	1.90	.14
Depreciation of machinery	3.37	2.04
Depreciation of building	0.76	.58
Taxes	0.13	.55
Insurance	1.88	.09
Management		
Management and selling	7.60	5.10
Warehouse and		
Lumber Handling	-----	.46
Total Annual Operation		
Costs	88.08	86.50
Estimated Annual Sales	100.00	100.00
Profit before Taxes	11.92	13.50
Cost of chip manufacture		11.65
Particle Board Plant Profit		1.85

[1]All figures are based on $100 of annual sales for lumber and $100 of annual sales of particle board. Only a limited quantity of particle board can be made under these exact conditions: where the total log costs are paid by the sawmill and only the sawmill residue is used to make particle board. The figures purposely are not given on a per ton, per board foot, or per square foot basis.

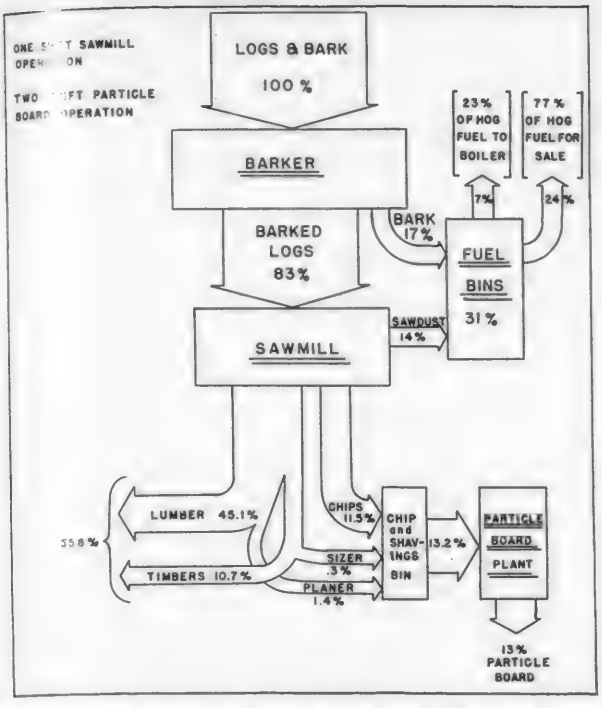


Fig. 1.—Material balance for 40M/shift sawmill, one-shift sawmill operation, two-shift particle board operation.

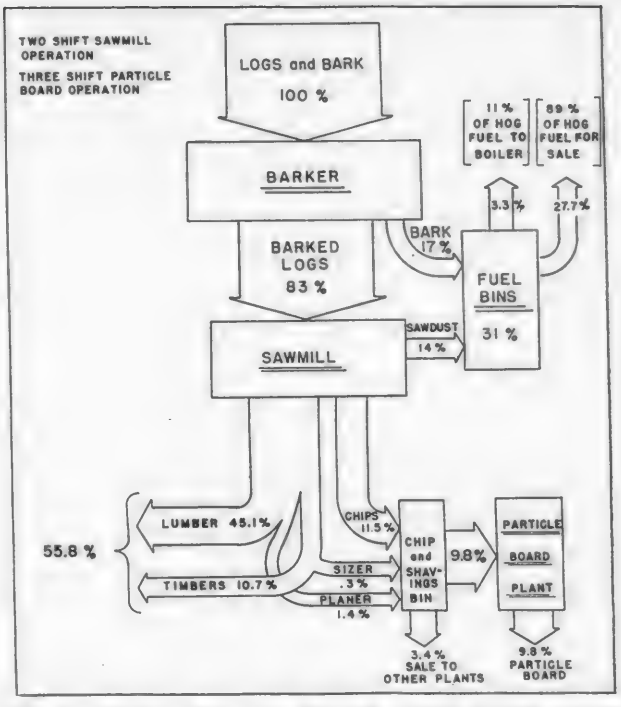


Fig. 2.—Material balance for 40M/shift sawmill, two-shift sawmill operation, three-shift particle board operation.

2) The logs are debarked, which is necessary so that all the residue waste from the log can later be made into chips suitable for further processing. Bark cannot be processed to make the same products, and degrades the product if much of it is used.

3) The logs are then sent to the sawmill where they are sawn into lumber, cants, and timbers. These are stored for shipment or further processing in the mill yard.

4) Some of the lumber is dried in the dry kiln, and is then planed and stored under cover for shipment. Other lumber is planed green, then stored under cover for shipment.

5) The sawmill waste consists of slabs, edgings, trimmings, and sawdust. All but the sawdust is sent to the chipper to be flaked into particles suitable for further processing.

6) The flaked sawmill residue is conveyed to the particle board plant, where it is mixed with glues and pressed into boards. The boards are then stored in the dry-storage warehouse.

7) The bark from the debarking machine and the sawdust from the sawmill are either used as fuel by the integrated plant or sold to other fuel users.

Material Balance, Manpower Requirements, and Profit on Annual Sales

Material Balance: An engineer designs a plant on an input-output basis; that is, how much and what kind of material goes in one end, and how much and what kind of material comes out the other end. In this forest products plant, logs go in one end and lumber and particle board come out the other. There is also a certain amount of bark and sawdust to be used for fuel. The question is, for a given amount of logs, how much lumber, how much particle board, and how much fuel is made. When we know this, we have the "material balance" around which we can design the plant.

Fig. 2 shows the material balance of this plant on a single-shift sawmill, two-shift particle board plant basis. For every 100 per cent of log fed into the barker, 55.8 per cent is converted to lumber and timbers, and 31 per cent becomes hog fuel, of which 23 per cent is used for boiler fuel within the plant (this is strictly for heat supply for the dry kilns and particle board process). The chips from the sawmill residue, planer, and timber sizer just equal the particle board plant demand, so that 13.2 per cent of the log is sold as particle board.

This illustration shows at once the difference between a sawmill that merely burns its residue to get rid of it and one that ultilizes its residue to make a saleable product.

Fig. 3 emphasizes another point. When the sawmill operates two shifts and the particle board plant three shifts, not only is a larger amount of particle board manufactured, but an excess of chips is made available for sale for a cash income. This particular plant is so situated that chip-sale possibilities are excellent. The chip excess occurs because the log intake is doubled in the two-shift operation, but the particle board plant increases its output by only one-half when it goes from a two-shift to a three-shift operation.

The material balance is excellent in the one-shift sawmill—two-shift particle board operation, with only the excess hog fuel to be sold or otherwise disposed of. The material balance is good with a two-shift sawmill—three-shift particle board operation, with both excess chips and excess hog fuel left to be sold or otherwise disposed of.

Manpower Requirements: Operating costs of the integrated plant are based to a great extent on the manpower requirements. By using highly mechanized and automated machinery, these requirements have been kept to a minimum.

On a single shift operation, total manpower requirements are expected to be:

1. Sawmill, planing mill, and dry kilns	18 men
2. Particle board plant	4 men
3. Shipping and warehouse	4 men
4. Maintenance crew	6 men
5. Supervisory and sales personnel	28 men
Total	60 men

Certain building materials are bought and sold by this company, so that the sales, supervisory, and warehouse personnel will also handle these items.

The personnel in sales and supervision will not be increased for two-shift operation, so a considerable operating-cost savings is realized by operating the plant for more than one shift. The firm plans to operate the sawmill one or two shifts, as the market demands, and, similarly, to operate the particle board plant two or three shifts.

Apparent Profit on Annual Sales: Flexibility is built into this operation by tying the number of shifts operated to the market conditions and by planing and drying according to market conditions. The figures presented assume a poor market, which requires the sawmill to run only one shift and the particle board plant two shifts.

Table 1 takes into consideration the operating cost and fixed investment items, and shows the apparent annual profit per $100 of sales realized under these conditions. This profit is taken before taxes, and the term "apparent" is used to provide for the contingencies that occur in every type of plant operation.

These figures are taken from a series of complete accounting-type spread sheets, which examine each phase of the operation individually and then make a composite of them all. Since all the logging costs are allocated against the sawmill and none against the particle board plant, the apparent profits are weighted heavily in favor of the particle board plant.

The figures show that of every $100 of annual sales of sawmill products, the sawmill would earn a profit of $11.92, and for every $100 of annual sales of particle board products, the particle board plant would earn a profit of $41.85.

Conclusion

The small, integrated plant is a practical and profitable enterprise. It must be engineered for economical operation by utilizing the latest advances in sawmill design, material-handling methods, planing-mill layout, semi-automatic dry kiln operation, and a particle board plant of the capacity to fit the residue output of the sawmill.

The advantages of the small, integrated plant are: 1. comparatively small initial investment; 2. good profit margin per sales dollar; 3. flexibility and economy of operation; and 4. comparatively small timber holdings required for justification on a long term basis.

On the basis of this study, it would seem that the small, integrated plant is indeed the best forest products plant for today and for the foreseeable future.

ATTEMPTS TO MODIFY THE

Weathering of Redwood[1]

Fig. 1.—California Redwood Association test fence at Cloverdale.

W. A. Dost
Calif. Redwood Assoc.,
San Francisco

The most desirable finishing shown for redwood is to allow it to weather without any treatment. Present research is aimed at chemical modification of extractives, solvent seasoning to remove extractives, and improving water-repellent preservatives.

NATURAL REDWOOD EXTERIORS HAVE a long history of popularity in the West. In the early postwar years, the popularity of natural redwood spread to other sections of the country, and many people began to look for finish systems that would keep its appearance from changing. As a consequence, the California Redwood Association began to receive m y letters inquiring about the most s isfactory natural finish materials an their application.

The association's initial reacti was to suggest reliance upon the com-mendations of reputable finish man-ufacturers, and with replies a st of reputable firms was enclosed. ortly after this, reports were receiv that indicated these suggestions w not

[1] Presented at the Spring Meeting, FPRS Northern California Section, May 2, 1958, Berkeley.

Fig. 2.—Surface repellency is evaluated here on the basis of the water trail. The board is inclined at 45°, and a single drop of water is allowed to fall on the surface from a distance of about 1 inch.

resulting in satisfactory finish performance.

Natural Finish Systems Were Evaluated

As a result, a program of evaluation of proprietary natural finish systems was undertaken. This program was partly successful. After several years of testing, it was possible to supply a list of film-forming finishes that in most climates could be expected to perform for from 18 to 24 months before refinishing became necessary, This performance was much better than the average durability of similar products that had been tested. These materials however, still failed in a manner that frequently required complete removal of the old finish in the process of refinishing. This situation exists at the present time.

No Finish At All Is Most Desirable

When it became evident that film-forming systems were not able to give the desired performance, the problem was re-analyzed. The Association believes that, for redwood, the most desirable finishing system possible is to allow the wood to weather without any treatment at all. The relatively good acceptance of bleaches as exterior finishing materials indicated that a weathered exterior would be satisfactory if the color was reasonably uniform over the entire structure and was "clean" in appearance.

In the normal course of weathering, wood passes through an initial period of darkening followed by a gradual lightening to tones of silver gray. With redwood, there are two distinct mechanisms that cause this darkening. They are: migration of the redwood extractives to the surface of the wood, and mildew growth on the surface. The discolorations that result from these actions are readily distinguishable from each other.

Unfinished Exteriors Gain Despite Darkening

Extractive migration causes the less difficult problem to solve. It results from cyclic changes in moisture content, and causes the water soluble extractives to be carried to the surface of the wood and deposited there as the moisture leaves. Once on the surface, they form dark, reddish-brown stains. Because they are water soluble, these stains are usually leached away by rainwater where the surface is not protected. Extractive discoloration is common on unfinished exteriors in those areas protected from the rain. Periodic flushing of these areas with water from a garden hose will reduce stains of this sort to non-objectional proportions, and washing with a stiff-bristle brush and detergent will remove them.

Mildew, on the other hand, causes a general darkening of the wood when it is exposed to the elements. The discoloration is due to the presence of black mildew spores on the surface, and is generally the principal discoloration when the surface is exposed to rain. A simple check for the presence of mildew spores may be made by placing scotch tape on the wood surface, transferring the tape to a microscope slide glass, and examining this slide with the aid of a microscope. While mildew spores cannot be rinsed away with water, they can be very effectively removed by a light scrubbing with a bristle brush and detergent.

Unfinished exteriors are becoming more and more popular in spite of these darkening processes—processes which, in appropriate settings, tend to enhance the appearance of the wood. In addition, the increasing influence of oriental architecture on western design with its extensive use of unfinished woodwork is making this treatment stylish. A very strong financial motive is also involved, since there is no expense for maintenance.

Darkening Can Be Prevented

Most people, however, do not yet appreciate the advantages and beauty of this finishing procedure and want to give the wood a treatment that will maintain the original appearance, or make the change in appearance fairly uniform over the entire structure.

There are several ways in which the darkening of unfinished exterior woodwork might be avoided. They include chemical modifications of the extractives near the surface of the wood, processing to remove the extractive materials to some depth, and treatment with either a water-repellent, a preservative, or both.

Chemical Modifications of Extractives

Some chemical treatments have been investigated. In one program, redwood was exposed to various halogens, hydrogen halides, and nitrogen dioxide. Preliminary results indicated that some of these treatments rendered many of the redwood extractives insoluble in water, and limited evidence indicated that the inherent toxicity of the extractives was increased. It was found, however, that the colors produced were unstable when exposed to ultraviolet light.

Another program studied a number of titanium esters as reactants with the redwood extractives. In some cases, the esters did react with the extractives to form water-insoluble compounds. None of these treatments indicated any significant value when exposed to light. The same study included a large number of other compounds that did not combine with the extractives, and one group, polyamides, that not only combined with the extractives but also had the ability to react with many types of film formers. Investigation of the polyamides is continuing and natural weathering tests indicate that these materials may have value, at least as the first coat of a two- or three-coat system.

A study currently under way at the Stanford Research Institute is investigating diazonium salts for possible redwood treatments. In theory, it should be possible to couple these salts with the phenolic redwood extractives to form water-insoluble, light-stable, reddish or brownish dyes. The dyes thus formed would be similar to the "ParaReds" known to the pigment and textile industries for many years, and could probably be deposited in the wood to some depth. It has been demonstrated that the dyes can be produced in redwood. Their resistance to the degrading actions of sunlight and water has not yet been tested.

Solvent Seasoning to Remove Extractives

Another approach is the removal of the extractives near the surface of the wood. Solvent seasoning has been investigated by many people in the past. A major difference between redwood lumber dried in this manner and that dried in conventional kilns is this: in conventional kiln drying, the extractives tend to concentrate at and near

the surface of the lumber, while in the solvent seasoning process, the extractives are depleted at the surface, and are removed by the drying medium. The possibility exists that, by removing these extractives, food available for mildew growth would be materially reduced, and extractive migration to the surface during weathering would be minimized or eliminated. Material to check this theory has been prepared with the new solvent seasoning equipment at the California Forest Products Laboratory, and test exposures will be made in the near future.

Water-Repellent Preservatives

Treatment with water-repellents or water-repellent preservatives has attracted a great deal of interest in the last few years. Several manufacturers in the redwood and other regions are marketing lumber treated in this manner. Treatment with one of these materials raises the quality of wood products in several ways. It improves the dimensional stability by retarding moisture pick-up, and it minimizes the amount of rain water that gains access to the back of the siding by reducing capillarity and wetting through joints. In the case of water-repellent preservatives, treatment gives the wood surface a certain toxicity to fungi, including the mildews, which are responsible for the dingy appearance that often results when wood is allowed to weather without any treatment.

The experience of the California Redwood Association has been almost entirely confined to the paintable water-repellent preservative category, and tests have been made to evaluate the suitability of these products as natural finish treatments. The results indicate that the performance of these materials depends to a large extent upon the conditions of exposure and the weather during the test period. Performance apparently is quite closely related to the amount of precipitation that falls on the wood after the surface has lost its water repellency. When the preservative is present on the surface of redwood in sufficient amounts, mildew will not grow. The treatment also reduces, but does not prevent, extractive migration.

Major Problems: Short Service Life, Iron Contamination

When exposed to the weather, redwood that has been treated with a water-repellent preservative will first change to a reddish-tan and then gradually fade to a light tan or buckskin color. Areas that are subjected to frequent wetting finally change to a soft gray. Graying may be delayed, but not prevented, by periodic retreatment as necessary to maintain surface water repellency. Extractives that sometimes accumulate on surfaces that are protected from rain may be removed by flushing with water.

Two major problems have become evident in the use of water-repellent preservatives as natural-finish treatments. The first is their relatively short service life when exposure conditions are severe. The second, iron contamination, may result when materials are improperly stored or handled.

At the Cloverdale test site, panels are exposed, without protection such as a sidewall receives from a roof overhang, to a climate characterized by fairly wide daily fluctuations in temperature, high nightly humidity, and much sunlight. It was found that pronounced mildew attack can occur in less than one year, and that the water repellency of exposed surfaces is also transient. Consequently, where the purpose of the treatment is to retain color and inhibit the growth of mildew, it is recommended that the water-repellent preservative be applied each year prior to the rainy season. Where the exposure conditions are not so severe or where color retention is not important and the purpose of the water-repellent treatment is to reduce the penetration of water into the siding and through the joints between pieces of siding, this frequent retreatment is not necessary.

Sources of Contamination

The second problem is serious only when the appearance of the water-repellent treated redwood is important. In a few instances, applications of water-repellent preservatives have resulted in a bluish-black discoloration. Investigation revealed that the discoloration resulted from an iron contamination of the water repellent. The discoloration appears when the contaminated water repellent is applied to wet redwood or when the surface of redwood that has been treated with a contaminated water repellent becomes wet.

While contamination does not interfere with the functioning of the water repellent, a contaminated water repellent should not be used on redwood if the resultant bluish-black discoloration may be objectionable.

Contamination may occur during manufacture or subsequent storage. Also, it is known that, with some products, contamination may result if the water repellent is allowed to stand for several days in a partially empty container. A contaminated water repellent usually has a wine color rather than an amber or light-brown color. The darker the wine color, the greater the degree of contamination.

Laboratory tests show that at least several of the commercial brands are capable of picking up iron on contact with the metal. Besides depending upon time, the amount of pickup depends upon whether the iron is bright or rusty and whether moisture or other metals are present. Further analytical work is being done to determine which constituent in these formulations is the one susceptible to contamination. It may be possible to eliminate this hazard by modifications in formulation that would not affect the performance characteristics.

(Since this paper was presented, at least one major manufacturer of paintable water-repellent preservatives has made formulation modifications. Limited tests indicate that the new formulation does not become contaminated by iron from the container.)

Water-Repellent Preservatives Are Best So Far

The water-repellent preservatives offer what, at the present time, seems to be the most satisfactory combination of ease of maintenance, low maintenance cost, and natural finish effect. Their use may be expected to become even more widespread as the products are improved by increasing the length of time that they are effective in providing surface water repellency and protection against mildew, and by minimizing the contamination problem.

There is increasing public awareness of the limitations of clear film-forming finishes. This awareness is illustrated by a statement contained in the proposed FHA Minimum Property Standards scheduled for adoption within a year. In effect, these standards will limit the use of clear film-forming finishes to those areas protected from both sun and rain, and will apply to all houses whose sales are financed with loans insured by the federal government. At the present time, this requirement is in the best interest of both the home purchaser and the lumber industry, and will continue to be until surface coatings with a more satisfactory performance are developed.

Many owners still prefer natural wood exteriors on their homes, but are reluctant to undertake the trouble and expense of maintaining clear surface coatings. The California Redwood Ass'n. is endeavoring to help these people by educating them to a better understanding and appreciation of the easily maintained natural treatments, among which the paintable water-repellent preservatives are, perhaps, the most natural. At the same time, through research, an attempt is being made to find other and better solutions to the problem.

TOWARD NEW AND BETTER MEANS OF

Dimensionally Stabilizing Wood[1]

The dimensional stabilization seminar, first of its kind in the U. S. was called at FPL to encourage and guide research on one of wood's most serious challenges. The meeting was organized by Dr. A. J. Stamm, pioneer in the dimensional stabilization of wood.

IMPREG DIE MODELS for the automobile industry represent the largest single commercial application for stabilized wood.

THE SCIENTIFIC QUEST for new and better means of stabilizing wood dimensionally got a powerful stimulus when some 85 scientists, educators, and industrial leaders from all parts of the United States and Canada examined information and exchanged ideas at the U. S. Forest Products Laboratory.

Twenty speakers reviewed past achievements, analyzed existing information and its results, and proposed new avenues of research intended to make wood products more stable whether of lumber, plywood, fiberboards, paper, or anything else made of wood fiber. Representatives of these industries, chemical manufacturers, forestry schools, and other laboratories were among those attending the seminar.

The keynote of the meeting was sounded by Dr. J. A. Hall, director of the federal laboratory, at the opening session:

"While by and large wood is still the best structural material we have, if we can come up with some constructive ideas we will have made as great a contribution to the serviceability of wood in our economy as can be made."

A challenge to get away from "traditional thinking" was put squarely before the group by C. D. Dosker, Louisville, Ky., industrialist and chairman of the products and research committee of the National Lumber Manufacturers Association. Dosker called for the trebling of present research expenditures on wood and its products, which he put currently at about $60,000,000 a year by all public and private groups in this country.

Recommendations for Future Research

Six recommendations for future work were drawn up by a committee headed by R. H. Bescher, Koppers Co., Pittsburgh, Pa., and including Dosker; L. T. Sanders, Crossett Co., Crossett, Ark.; J. F. Saeman, assistant director of the Forest Service division of forest products research, Washington, D. C., and J. A. Van den Akker, Institute of Paper Chemistry, Appleton, Wis. The recommendations, unanimously adopted, were:

"1. That substantial additional basic information is necessary on wood-moisture relationships, microstructure of wood, and basic chemistry of wood.

"2. That since the proper use of wood will minimize the limitations caused by lack of stability, the trade associations should be encouraged to publicize the proper engineering principles of use.

"3. That more economical means of mechanically stabilizing wood should be further investigated, particularly with regard to composite structure, press drying to cause mechanical extension, and the use of other mechanical methods of distributing and minimizing the effect of dimensional changes.

"4. That additional work be performed in connection with chemical stabilization of wood. Since bulking and cross linking appear to be the only chemical means of wood stabilization, newly developed chemicals should be screened. Fundamental studies of the extractives of wood should be undertaken to determine why some species are more stable than others.

"5. That in the dimensional stabilization of paper a fundamental investigation of the effect of species should be carried out.

"6. That a bibliography be prepared which would serve as reference material for further research in the dimensional stabilization of wood."

In drawing up its recommendations, the committee pinpointed the wood-moisture relationship "as being basic

[1] A summary report on The Dimensional Stabilization Seminar, held at the U. S. Forest Products Laboratory, Madison, Wis., Jan. 21-23, 1959.

Dr. Stamm holds a BS degree from the California Institute of Technology, and MS and PhD degrees from the University of Wisconsin. He joined the Forest Products Laboratory in 1925, among his achievements have been broad contributions to fundamental knowledge of wood-liquid relations and such highly stabilized products as impreg and compreg.

to the problem and to all approaches to the solution." Its report called for a scientific breakthrough in the basic fields of wood microstructure and chemistry of wood in order to "economically solve the problems."

Sessions of the seminar were devoted to consideration of these aspects of dimensional stabilization: wood and cellulose liquid relationships; minimizing the effects of swelling and shrinking by proper use; mechanical means of stabilizing wood; chemical means of stabilization; stabilizing paper and fabric; and chemicals for dimensional stabilization.

Wood and Cellulose Liquid Relationships

The chemical nature of wood excited sharpest interest and monopolized discussions as speakers probed deeply into its known relations to dimensional changes. Dr. Harold Tarkow of the FPL described wood's molecular structure as consisting of a backbone of cellulose chains that are linked together at certain points by chemical or physical bonds, but only loosely bundled together at other points, where moisture can enter or leave to cause swelling and shrinking. Among chemical problems being attacked is that of getting stronger bonds between the cellulose chains where these are loosely bundled together, or putting so-called "bulking agents" between the chains to fill up the spaces water otherwise enters and leaves.

One of the roadblocks thus far preventing successful chemical bonding of the cellulose chains, other speakers agreed, is lack of low-cost effective chemicals to do the job. Highly complicating this task, Dr. Tarkow pointed out, is the fact that even the electron microscope can't produce as yet clear pictures of the extremely small elements that make up the structure of wood fiber walls where swelling and shrinking actually occur.

"We don't even know," he said, "how large a molecule we can get into these cellulose bundles to form chemical cross links or bulking compounds that will stop swelling and shrinking. When we find that out, we will be in a better position to tell chemical companies what we need."

In some wood species, Dr. Tarkow said, extractives act as bulking agents, and these species generally shrink and swell less than others.

Dr. F. F. Wangaard of the Yale University School of Forestry, New Haven, Conn., diagrammed the mechanism of wood swelling and shrinking as understood from existing knowledge. A parallel discussion of the same phenomenon in other fibrous materials, notably cotton and rayon, was presented by Dr. Howard J. White, Jr., Institute for Textile Research, Princeton, N. J.

Minimizing Shrinking and Swelling by Proper Use

Much of the harmful effect of swelling and shrinking in wood construction, including furniture, houses, and other buildings, could be avoided, several speakers said, if better use were made of existing knowledge about how to season and handle wood. Fred E. Dickinson, director of the University of California Forest Products Laboratory at Berkeley, emphasized that the construction industry is the biggest market for wood but that other materials are challenging wood more strongly than ever.

That the lumber industry has too long underestimated the importance of moisture content of wood in use was cited by R. P. A. Johnson, former chief of the federal laboratory's division of physics and engineering (now retired), as one reason why wood has lost some of its markets.

"We know what to do," he charged, "but industry doesn't do it, and the consumer doesn't demand it. We've suffered from an attitude of 'good enough,' but today good enough isn't good enough any more. Manufacturers of other materials are doing a lot of research to make their products equal to or better than wood. As long as we're content with good enough, our markets will continue to vanish."

The air-conditioned home will bring new problems of moisture stabilization in wood-work, furniture, and other wood products used in its construction, warned Raymond C. Rietz, in charge of seasoning research at the FPL.

"We went through this once before," he recalled, "when central heating brought marked changes in the conditions to which wood is exposed in houses. We need a nationwide study of moisture conditions in houses that are air conditioned, in order to get accurate information on the proper degree of seasoning for wood used in such buildings."

Otto Heyer, of the FPL, pointed out that, although light frame construction has become a tradition, poor framing is still not uncommon. The framing of the "hybrid" split level especially may result in unbalanced construction and further complicate shrinkage problems.

Another member of the Laboratory staff, Don Laughnan, stressed the limitations of finishes in restraining wood. "It is not possible", he said, "to keep wood at a given moisture content by applying a finish, whether of the surface-coating or penetrating type". Finishes simply retard the rate of exchange of moisture between wood and its ambient atmosphere.

Dimensional Stabilization of Wood by Mechanical Means

Adhesives play an important role as mechanical means of curbing swelling and shrinking in such products as plywood and fiberboard, Dr. George C. Marra, Washington State Institute of Technology, Pullman, Wash., told the group. He described research aimed at developing better bonds in such products as particle board and chipboard.

Progress in curbing swelling and shrinking with paper overlays glued to low-grade lumber was reported on by B. G. Heebink, also of the FPL. He described the laboratory's process for stabilizing veneer by drying it in a hot press under restraint.

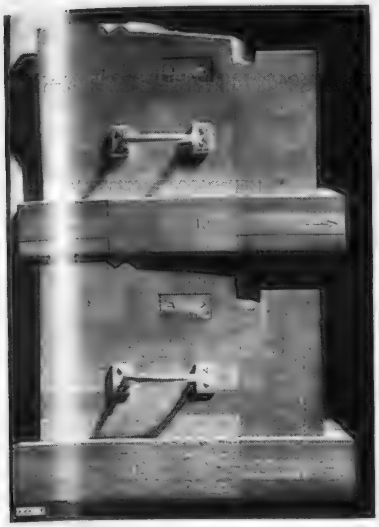
F. A. Bade, Jr., General Plywood Corp., Louisville, Ky., described the Supermicroseal process, which results in a slightly densified, glossy wood surface that is stabilized in depth. Apparently, a slight flow of lignin caused by the simultaneous action of pressure and frictional heat is at least partially responsible for this phenomena.

Dimensional Stabilization of Wood by Chemical Means

Chemical treatments to cross-link the cellulose chains in the cell walls of wood more firmly together or bulk them apart with insoluble chemicals aroused some of the most spirited discussions. Dr. E. C. Jahn of New York State University College of Forestry at Syracuse stressed the need for better knowledge of wood structure and paid tribute to Dr. Stamm's pioneering work, calling him the "Dean of Stability."

His recent work with polyethylene glycol as a stabilizing agent in wood, based on previous results with inorganic salt solutions, was reviewed by Dr. Stamm. He said it has been possible to replace all the water in thin sections of wood with this bulking material and thus stabilize the wood at its green dimensions. The chemical does not affect the toughness of wood, has only a minor effect on gluing and finishing, and at higher levels of treatment virtually eliminates decay.

Experiments with formaldehyde as a cross-linking chemical in wood first treated with an acid salt catalyst were also described by Dr. Stamm. While swelling is reduced as much as 80 per cent, the wood is seriously embrittled.



Absence of shadows on impreg die model (lower) shows lack of dimensional change during exposure to high humidity. Upper model is of standard mahogany lumber.

Nevertheless, Dr. Stamm declared, the principle of cross linking is a sound one and should prove commercially feasible if the right cross-linking chemical can be developed—one that will react with wood in the pH range of 4.5 to 8.

The successful use of phenolic resin as a bulking agent, pioneered at the FPL and now commercially applied, was discussed by R. M. Seborg. Costs limit its usefulness, he said, to such high-value items as forming dies and jigs for metal working, and patterns for steel dies used to stamp auto parts.

The acetylation treatment developed at the FPL was reviewed by Dr. Tarkow. He showed how the reaction imparts stability to the wood by bulking. The main drawback to the process is the corrosive action of the chemical on processing equipment and the fact that only half of the acetic anhydride molecule used enters into the reaction.

Dr. J. Risi, professor of wood chemistry at Laval University, Quebec, reviewed his experiments on alkylation and acylation of wood and its reactions with various isocyanates and diisocyanates. These usually caused varying degrees of degradation of the wood due to side-reaction products. He suggested possible new chemicals that might avoid these effects on wood.

Dr. Risi also suggested that, instead of gross bulking of the internal structure, research be directed toward obtaining only thin films of water-repellent materials on the internal surfaces to act as barriers to entry of water into the cell-wall structure. Such coatings, he maintained, would require much less material.

Cyanoethylation with acrylonitrile was described by Dr. Irving S. Goldstein, Koppers Co., Verona, Pa., as a bulking treatment that reduces swelling of wood as much as 75 per cent and also reduces the equilibrium moisture content of wood. He told of experiments with beta-propiolactone, a bulking agent that reacts without the aid of a catalyst. It does not affect the toughness of wood, but gives high resistance to swelling.

Dimensional Stabilization of Paper and Fabric

Wood fibers are also responsible for swelling and shrinking of paper with changes in relative humidity, Dr. J. A. Van den Akker, Institute of Paper Chemistry, Appleton, Wis., emphasized. More stable fibers would be important to such products as business forms, map papers, patterns, and template papers.

Moisture stabilization experiments on paper conducted at the National Bureau of Standards, Washington, D. C., in a search for a better military map paper were described by Dr. Gerald L. McLeod. Stability was improved, he said, by blending glass fibers with cellulose fibers and by laminating thin map paper to a more stable film.

A joint investigation on cyanoethylation of paper was described by N. M. Bikales of American Cyanamid Co. in cooperation with John L. Morton of the International Business Machines Corp., New York. Experiments were carried out on wood pulp as well as on paper. Treated pulp imparted substantial dimensional improvements to paper made from it.

Considerable success in dimensionally stabilizing paper containing a zinc chloride catalyst was reported by Dr. Stamm, who used both heat treatments and a process involving cross-linking with formaldehyde. Formaldehyde cross-linking had less detrimental effect on the strength properties of paper than did heat treatment.

Paper cross-linked with as little as 0.5 per cent of formaldehyde, he pointed out, reduced swelling and shrinking by 60 per cent without affecting the tensile strength.

Possible Chemicals for Dimensional Stabilization

Of the two chemical approaches now being used experimentally to stabilize wood, chemical cross-linking of the cellulose chains looks like the more effective, said Dr. E. G. Locke, chief of the FPL's division of wood chemistry, in opening a panel discussion of new chemicals for wood treatments. The final session of the meeting consisted of round-table discussion by representatives of chemical manufacturing companies.

Harold Wakefield, Union Carbide Plastics Co., New York, pointed out the need for finding new chemicals that could be used in dimensional stabilization studies that would readily react with the components of wood in small quantities without significant loss in strength properties and at a reasonable cost. He pointed out that some of these reactions might be catalyzed by nuclear radiation to avoid the embrittling effects of acid and alkali catalysts. Irradiation at high energy levels might have a severe degradative effect on wood, and he warned that irradiation would have to be used with caution.

Duane Kenaga, Dow Chemical Co., Midland, Mich., described experiments made at Dow on the effect of gamma irradiation on ponderosa pine (paper in this issue of the JOURNAL). He pointed out that at high energy levels the degradation was quite severe. He said also that irradiation had little effect upon hygroscopicity of wood when used alone, but that combined with certain chemical treatments it might promote cross linking.

J. W. LeMaistre, Atlas Powder Co., Wilmington, Del., said he was impressed by the high effectiveness of formaldehyde in stabilizing both wood and paper. He suggested that the embrittling effect obtained with the short cross links obtained with this compound might be reduced by using larger molecules that would not form so stiff cross links as formaldehyde.

A. C. Nixon, Shell Development Co., Oakland, Cal., indicated that acrolein, which is extremely reactive, might cross link through the aldehyde group as does formaldehyde, and also react at the double bond, thus making possible three points of reactivity in the molecule. Because of its relatively low molecular weight and volatility, he indicated that it might be suitable for vapor-phase treatments. He cautioned that this chemical would have to be used with care because of its toxicity, but added that it was not too dangerous to work with because its effect upon eyes and nose, while still well below toxic levels, caused the investigator to be extremely uncomfortable before the danger level was reached.

N. M. Bikales, American Cyanamid Co., Stamford, Conn., showed the chemical similarity of acrylonitrile, acrolein, and acrylamide. The latter is, however, a relatively low-toxicity, water-soluble solid. It can be polymerized to water-soluble polyacrylamide polymers that could be impregnated into wood. Acrylamide can also be reacted with formaldehyde to form

methylolacrylamide. Part of the formaldehyde molecule reacts with the acrylamide and the other part is available to react with cellulose or wood. The same reaction between polyacrylamide and formaldehyde is possible. The polymer is still water soluble, so it could be impregnated into wood. The interesting feature of this material is that on heating it will cross link either with itself or with cellulose. It is thus possible to insolubilize the chemical in the wood after impregnation.

R. K. Madison, American Cyanamid Co., New York, N. Y., briefly described research being conducted on graft polymerization of various monomers with cellulose. The proportions can be varied over such a broad range that properties varying all of the way from those of the pure polymer to those for cellulose can be obtained. He also suggested that diepoxides might be used as cross-linking agents.

Dr. Stamm, who is retiring from the Laboratory after some 30 years of research, pointed out the desirability of chemical companies sending representatives to the Forest Products Laboratory occasionally so as to acquaint the Laboratory with new chemicals that might not only be used in the dimensional stabilization of wood and paper but might also be suitable for modifying other properties of wood and its products.

"I know that the Laboratory will continue research in this field," he said, "and I am confident other laboratories will accelerate their research. I think this meeting is a good step toward getting the kind of teamwork we need among laboratories. And let's not poo-pooh ideas that may sound a little strange at first. Some of these wild ideas, we may find, aren't so wild after all."

"If this panel hasn't done anything else than alert chemical companies to the possibilities of finding new uses for their products at this and other laboratories," Wakefield said, "it will have served its purpose."

The need for expanded work in many laboratories was also stressed by Director Hall.

"It can't be done in any one or half a dozen institutions," he said. "I'm not worried about duplication of effort. We've had many examples here of men who took the same tools and went through the same motions and came out with diammetrically opposite results. This is an extremely complex problem, and we've a long road ahead to achieve a fiber with the properties we want. I hope that the chemical companies will realize that this field of additives to wood represents a tremendous potential market and will keep it in mind in their research."

Summing up the seminar results, Dr. Tarkow emphasized that chemical stabilization is not necessarily a cure-all.

"It occurs to me," he said, "that perhaps we have been shooting too high in our efforts to stabilize wood. Do we have to make it completely stable, or is 30 or 40 per cent stabilization useful? Can we use wood that has been somewhat weakened by stabilization treatments?"

He pointed to the possibilities of genetics research in developing strains of trees with "built-in" bulking agents, such as trees with higher amounts of extractives, and in pursuing means of stimulating natural "cross-linking" of cellulose in the growing trees.

"Industry," Dosker declared, "will be very much interested in the work that comes out of this seminar. By sponsoring it, the Forest Products Laboratory has made possible a great forward step in this research."

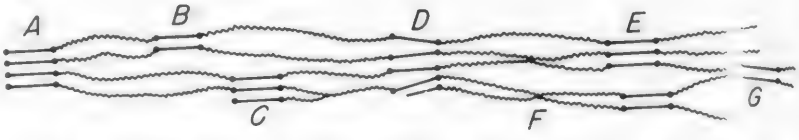


Fig. 1.—Schematic drawing of swelling network in cell wall substance. Lettered regions indicate a few of the many types of ordered regions.

GENERAL SUMMARY OF THE FPL

Wood Stabilization Seminar

HAROLD TARKOW
Chemist, Forest Products Laboratory[1] Forest Service, U. S. Department of Agriculture

TWO INDEPENDENT FACTORS ARE INVOLVED in the swelling of cellulosic materials: internal swelling of solid substance, and the transmission of this swelling to the external dimensions. For example, papers made from a given pulp stock may show similar equilibrium moisture content—and, therefore, similar internal swelling—yet their external swelling may vary widely, depending on formation variables.

This dual aspect of swelling means that, basically, two general procedures are available for its reduction:

1) Reduction in the amount of internal swelling.

2) Reduction in the amount of swelling transmitted to the external dimensions.

Reduction in Internal Swelling

Fig. 1 is a *highly schematic* model of the skeleton of wood substance. The model consists of long chains of cellulose roughly parallel to each other. Here and there (A, B, C, E, and G) the chains are reasonably parallel and equidistant from each other. Elsewhere (D), the degree of parallelism is poorer or the uniformity of the spacing is interfered with. Still elsewhere (F), isolated chains come together at a single point.

A large variation in degree of order exists, which may be due in part to the presence of lignin or hemicellulose between chains. The somewhat orderly regions have varying degrees of inertness toward moisture. The segments or contents between these regions adsorb moisture at specific sites or adsorb clusters of water molecules between segments. The segments must separate after adsorption; however, since they are "tied" at their ends, they are subjected to an elastic stress, which soon opposes further separation at a particular relative humidity. An equilibrium moisture content is then attained. The amount adsorbed depends on the number of sites, the chain flexibility, and the length of segment between regions of order.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

At equilibrium, the force that tends to drive the moisture into the network, which is related to the relative humidity, is just balanced by a force that resists swelling, which is related to segment flexibility and length. Swelling can be reduced by decreasing the driving force or by increasing the swelling resistance.

Decreasing Driving Force: The obvious way of decreasing the driving force is to apply a uniform, impermeable coating around the specimen. This is perhaps one of the oldest methods in use. No coating is impermeable, however, and if exposure to a high or low relative humidity is prolonged, dimension changes will occur. Where such exposure is of short duration, because of the retardation of moisture movement by the coating, dimension changes are very small. When properly formulated and applied, such coatings reduce seasonal variations in moisture content of outdoor exposed panels.

Increasing Resistance to Swelling: One method of increasing wood's resistance to swelling is to decrease the length of the segments between ordered regions. (Fig. 1). Qualitatively, the effect is similar to that obtained by vulcanization of rubber. Reduction in segment length can be obtained by introducing more junction points (similar to F. in Fig. 1) Thus, methylene linkages are introduced between segments by treating wood with formaldehyde under acidic conditions.

A very serious limitation, however, is the acid-catalyzed degradation that accompanies the primary reaction. Other cross-linking agents were suggested. Formaldehyde, however, is unique. Because of its low molecular weight, very appreciable reductions in swelling are obtained with small uptakes of chemical (1 to 2 per cent for example). With other cross-linking agents of much higher molecular weights, to introduce the same number of additional crosslinks may require chemical uptakes that are no longer insignificant, even if steric complications are ignored.

A second method for effectively increasing the resistance to swelling is to deposit something within the wood substance that permanently bulks out or elastically stretches the network. Regardless of exposure, the prestrained condition limits the amount of moisture that can be absorbed. Such a procedure is involved in resin impregnation, chemical reaction with acetic anhydride, beta propiolactone, and perhaps cyanoethylation. The desired effect depends primarily on the volume of material placed in the cell walls, and seems to bear little relationship to the direct removal of hydroxyl groups.

Since stabilization by this procedure depends on placing about 20 cubic centimeters of material in 100 grams of wood substance, and is independent of the nature of the material used, the cost of such chemical can be computed. Unfortunately, this is not necessarily the cost-determining phase. The ultimate cost is determined more by the cost of getting the chemical into the wood substance, and of getting by-products out, if they are formed. This generally requires the use of veneers, which is accompanied by high handling costs. A reference (Goldstein), however, was made to the successful acetylation of 1-inch boards.

Reduction in External Swelling by Reducing the Extent of Transmission of Internal Swelling

Historically, plywood is the prime example of how swelling has been reduced by curbing the extent to which internal swelling is transmitted. The equilibrium moisture content or internal swelling is essentially unaffected, but external swelling is markedly reduced by restraints imposed because of directional differences in swelling of wood.

A similar, but less effective, result is obtained by overlaying boards with resin-treated paper. A fairly strong paper properly bonded to wood may reduce the swelling of the board by 30 to 40 per cent. Reductions in external swelling of papers are obtained by adding nonswelling plastic fibers to the furnish. There was a great deal of interest in these mechanical procedures, and one got the feeling that further work should be done in combining cellulosic materials with other materials. The use of "swelling sinks" was described. These consist of deliberately created cracks that permit internal swelling without influencing the external dimensions.

The meetings left one with the impression that we are still far removed from a universally applicable, high-performance, dimension-stabilizing treatment. Questions were raised whether lesser treatments would not find uses and, of course, with this in mind, it was felt that further work should be done with some of the newer reactive chemicals mentioned by the representatives of chemical industry who attended the meetings. The field, however, is urgently in need of additional fundamental information. As one listened to the papers, questions came to mind whose answers could be very useful toward a solution of the problem of dimensional stabilization; for example:

1) What is the order of magnitude of the spacings between chain segments in the nonorganized regions (Fig. 1)? This has a bearing on the effect of molecular size on the ease of penetration into wood substance. This problem could be pursued by means of penetrants of graded molecular size or by studying osmotic pressure effects.[2]

2) What is the nature of the fiber-to-fiber bond in paper or fiberboard? This is important because of its influence on the transmission of the internal swelling to the external dimensions.

3) What is the effect of fiber processing on fiber rigidity? This, too, could influence the transmission of internal swelling.

4) What is the condition of adsorbed water at different relative humidities? Satisfactory work in the past has been hampered because of the lack of suitable techniques. A procedure based on nuclear magnetic resonance should be useful here. It is being used to examine the nature of water adsorbed on wool at various relative humidities.

5) What is the function of extractives in cell walls? This is not an idle question from the point of view of dimensional stabilization, for if we could learn how to stimulate such deposition, we would have built-in bulking agents. Such woods as teak and mahogany owe their low swelling characteristics to such deposits.

6) What is the nature of the submicroscopic structure of green wood? Does the structure we find in once-dried wood develop during drying, or is it present in the green tissue? If it can be shown that this structure develops on first drying, then we may be able to direct its development. On the other hand, if the submicroscopic structure is present in the green tissue, how is it related to seasonal variations in fiber saturation point? Are there genetic influences? Are there occasional strains in which the submicroscopic structure is one that inherently contains a greater number of natural crosslinks (or increased crystallinity)? Can such strains be propagated?

7) What is the condition of the "waxy" material in the cuticle of an insect? Why is it that such waxy layers are so efficient in preventing the loss of moisture from insects that inhabit dry desert areas? Fleshy fruits are protected against desiccation by naturally occurring deposits of "wax." Is there something peculiar about the composition of such deposits or about the way nature has laid them down? The importance of such information to improved wood finishes is obvious.

[2] Chem. Phys. 13: 363 (1945).

Effect of Gamma Radiation on Ponderosa Pine:

HYGROSCOPICITY, SWELLING, AND DECAY SUSCEPTIBILITY[1]

D. L. Kenaga and E. B. Cowling
Biochemical Research Laboratory, The Dow Chemical Co., Midland, Mich.

The effect of gamma radiation up to 10^7 reps was studied. Changes induced in the wood were small and not of practical importance in most instances. Analyses of variance indicate that future irradiation experiments on wood should take into account the total radiation dose applied, the dose rate, and the moisture content of the wood at the time of irradiation.

HIGH-ENERGY RADIATION is being intensively studied as a means to alter and improve the chemical and physical properties of many high-polymeric materials. Such radiation applied to wood, alone or in conjunction with chemical treatment, potentially will provide new means to modify and improve such wood properties as dimensional stability and decay resistance. The effect of radiation on the wood itself must be determined, first, however.

The present study was designed to evaluate the effects of the highly penetrating gamma radiation emitted by cobalt^{60} on the hygroscopicity, swelling, and decay susceptibility of ponderosa pine sapwood. Variables tested include the total radiation dose applied, the rate at which the dose was applied, and the moisture content of the wood at the time of irradiation.

Literature Review

A compilation of references published prior to July 1955 on radiation effects of high-polymeric materials was prepared by Pecjak and Sun (10)[2]. Sun (14) has also reviewed much of this literature. Mark (7) and Mater (8) have described the effects of high-energy radiation on certain chemical and nutritive properties of wood, and have discussed possible future economic uses for irradiated wood products.

Degradation is the primary effect of high-energy radiation on cellulose and wood at high dose levels. This was first shown by Lawton and others (6), who demonstrated that basswood undergoes moderate degradation at 10^6 reps[3] in a high-velocity electron field and becomes almost wholly water soluble at 3.3×10^8 reps. Saeman, Millett, and Lawton (13) confirmed these results with cotton linters, wood pulp, and extracted spruce wood. They found that, at dose levels greater than 10^6 reps, these materials undergo progressive and simultaneous depolymerization, reduction in crystallinity, and degradation of liberated oligo-and monosaccharides. The depolymerization was apparently random, and affected both the crystalline and amorphous regions of the cellulose so as to increase its susceptibility to hydrolysis by dilute acids. Pew (11) showed that irradiation with cathode rays at 10^6 to 10^8 reps more severely degraded the carbohydrates than it did the lignin of spruce wood.

Blouin and Arthur (2) found that gamma radiation at doses between 10^5 and 10^8 reps induced the following progressive changes in purified cotton: 1) depolymerization of the cellulose chains; 2) carbonyl and carboxyl group formation; 3) increase in alkali and water solubility; 4) decrease in tensile strength; and 5) small, but measurable alteration in moisture-regain capacity (hygroscopicity). Each of these effects was inhanced slightly by irradiation in oxygen as compared to nitrogen atmospheres. The moisture-regain values showed little change below 10^6 reps (they averaged 7.1 per cent), but fell to a minimum of 6.4 per cent at 4×10^7 reps, and started to rise again at 10^8 reps. It was concluded, however, that the magnitude of these small changes reflects no marked alteration in the submicroscopic structure of the fibers.

Paton and Hearman (9) have shown that the hygroscopicity of spruce wood is not affected by gamma rays at dose levels below approximately 10^7 reps, but is reduced slightly at about 10^8 reps.

Glegg and Kertesz (5) studied degradation of cotton and wood cellulose maintained at two moisture contents (0.26 to 0.33 and 3.3 to 5.6 per cent) during irradition by gamma rays at 10^3 to 5×10^5 reps. They found that though comparable viscosity changes were noted for samples of both moisture classes, the viscosity of the drier samples continued to decrease for a period of 30 days following irradiation, which suggests a so called "residual after-effect."

Using experimental data of Saeman and others (13), Charlesby (3) derived a theoretical formula that related the decrease in intrinsic viscosity of cellulose to the radiation dose of high-energy electrons applied. Arthur (1) has propsed a theoretical formulation of the mechanism of gamma radiation effects on the several molecular properties of cellulose studied by Blouin and Arthur (2).

A second important effect of high-energy radiation on cellulosic materials is to alter their susceptibility to enzymatic degradation. Lawton and others (6) have shown that wood, which is ordinarily immune to digestion by rumen bacteria, approaches the digestibility of hay after irradiation at 3.3

WHAT THIS RESEARCH MEANS

Radiation as a means of carrying out chemical processes, polymerizing monomers, grafting monomers to polymer chains, and crosslinking polymers is much in the chemical news in recent years. The possibilities of applying these techniques to wood to promote dimensional stability, decay resistance, and other improved properties are exciting to consider. An understanding of the effects of radiation on wood is necessary prior to initiating programs of this nature. This paper shows the decay susceptability and hygroscopic and swelling effects induced by gamma radiation in ponderosa pine sapwood at various moisture contents.

Editor

[1] A contributed paper, received August, 1958.

[2] Numbers in parentheses refer to the Literature cited at the end of this paper.

[3] A rep (roentgen equivalent physical) is that radiation dose which produces an energy absorption of 93 ergs per gram of tissue.

The Authors: Duane Kenaga holds a BS in chemical engineering, and a BS and MS in wood technology from the University of Michigan. He was formerly with the Southern Research Institute, Birmingham, Alabama.

Ellis Cowling holds BS and MS degrees from the State University of New York College of Forestry, and is currently a doctoral candidate at the University of Wisconsin conducting research at the U.S. Forest Products Lab. The work reported here was done while he was participating in the Summer Employment Program at Dow.

x 10^5 reps with high-energy electrons. Mater (8) described the unpublished work of Remmert and Butts, who found that radiation at 3.2 x 10^5 reps by either gamma rays or high-energy electrons markedly increased the susceptibility of Douglas-fir sawdust to rumen enzyme preparations. On the other hand, Reese (12) has shown that cellulolytic enzymes from fungi show progressively decreased activity on cellulose irradiated up to 3 x 10^6 reps. Above this value susceptibility increased, however, and reached the level of unirradiated samples at about 6 x 10^7 reps.

These references (2,8,9,11) indicate conflicting evidence as to whether radiation doses below 10^7 reps alter the hygroscopicity of cellulosic materials or increase their susceptibility to enzymatic breakdown. Only once have differences in moisture content at the time of irradiation been investigated (5). The present paper provides evidence regarding the nature and magnitude of gamma radiation effects on ponderosa pine sapwood. Part I deals with effects on hygroscopicity and swelling properties of the wood; Part II deals with its decay susceptibility.

Experimental Design

A factorial experimental design with the following levels of each variable was used for each test in Part I and Part II: 1) total radiation dose—controls (no irradiation), 10^2, 10^4, 10^6, and 10^7 reps; 2) dose rates—0.2, 0.4, and 0.6 megarep per hour; and 3) moisture content at the time of irradiation—oven dry, 12 per cent equilibrium moisture content, and saturated with water. Three replicates were used in Part I; four were used in Part II. The results of each test were evaluated by the analysis of variance and the multiple-range test of Duncan (4).

Preparation of Test Blocks

The test blocks for both Part I and Part II were cut from ponderosa pine sapwood (*Pinus ponderosa Laws.*). Their dimensions were two inches tangentially, 1 3/8 inches radially, and 1/4 inch in the direction of the grain. The material selected was uniformly slow-grown (20 to 24 rings per inch throughout) and free of visible defects. It has a slope of grain less than one inch in 24 inches of length. The same set of blocks was used for both the hygroscopicity and swelling tests of Part I. All of these blocks were cut from a single plank. They were carefully selected to include only blocks with nearly true tangential and radial faces. The maximum annual ring curvature allowed was 1/4 inch in the two-inch span of the blocks. All blocks used for the decay tests of Part II were cut from a second plank.

The test blocks were irradiated by placement for calculated time periods in appropriate positions relative to the cobalt^{60} gamma radiation source to achieve the total dose and dose rates required by the experimental design. Because of the highly penetrating nature of gamma radiation, uniform exposure of all portions of the test blocks may be assumed.

PART I: HYGROSCOPICITY AND SWELLING

Test Procedure

Randomly assigned blocks were conditioned to the moisture contents required by the experimental design, weighed to the nearest 0.005[4] gram to provide a check on the moisture content actually achieved, and immediately sealed in 3-mil polyethylene film to assure maintenance of their respective moisture contents during irradiation. Oven-dry conditions were achieved by heating at 105°C. for 16 hours; approximately 12 per cent moisture content was obtained by equilibrating the blocks with an atmosphere at 21°C. and 65 per cent relative humidity; saturated moisture conditions (175 to 200 per cent moisture) were achieved by vacuum impregnation followed by overnight soaking of the blocks in distilled water.

After they were irradiated, the blocks were permitted to equilibrate with an atmosphere at 25°C. and 76 per cent relative humidity, and were then weighted. Swollen radial and tangential dimensions of the blocks were determined (to the nearest 0.001 inch) by means of an Ames dial micrometer after soaking overnight in distilled water. The blocks were air dried and subsequently oven dried, weighed, and their tangential and radial dimensions determined once more.

The hygroscopicity of the blocks was expressed as the per cent equilibrium moisture content (based on the final oven-dry weight) achieved by the blocks at 25°C. and 76 per cent relative humidity. Corrections for drying hysteresis were applied to the blocks dried from saturated conditions. This correction was determined by a separate study with irradiated blocks.

Radial and tangential swelling was determined as the difference between the swollen and final oven-dry dimensions of the blocks, and expressed as a per cent of the latter value.

Results

Tables 1 through 3 contain the average hygroscopicity and swelling data for the replicate blocks in each test. Means are given for all blocks treated at a given level of each variable. Means not followed by the same letter are significantly different as shown by the multiple-range test of Duncan (4). Mean squares from the analysis of variance for each test are presented in the first half of Table 6. Variables that show a significant influence on the properties of the test blocks are indicated by asterisks from the appropriate mean squares.

[4] All weight measurements in this study were made to the nearest 0.005 gram.

Discussion

Hygroscopicity Test Results: Although differences among the means in Table 1 for the levels of each variable are relatively small, the effects of total dose and the interaction of total dose and moisture content were significant at the one per cent level. Comparison of the means for the five levels of total dose show that irradiation at 10^4 and 10^6 reps induced significantly lower hygroscopicity in the test blocks than that shown by the controls or induced by the other dose levels tested. This reduction in hygroscopicity of ponderosa pine sapwood follows the same pattern demonstrated by Blouin and Arthur (2) for purified cotton. Both of these observations are in contrast to those of Paton and Hearman (9), who showed that the hygroscopicity of spruce wood is negligibly affected below 10^7 reps.

The significant interaction of total dose and moisture content reflects enhancement of the effect of moisture content at 10^7 reps.

Swelling Test Results: No main effects were significant in the radial swelling test. However, all main effects and the interaction of dose rate with moisture content were significant in the tangential swelling test. This indicates that gamma radiation more markedly affected tangential swelling than it did radial swelling. It also reflects, in part, the greater precision of tangential swelling measurements. Comparison of the coefficients of variation in Table 6 for the tangential and radial swelling tests reveals that variation in tangential swelling for blocks treated alike (experimental error) is approximately half that for radial swelling.

Comparison of the means in Table 3 for the tangential swelling test at the several levels of each variable showed that a total dose of 10^2 reps induced significantly greater swelling than did the other total dose levels tested. Irradiation at a dose rate of 0.2 and 0.4 megarep per hour and at saturated moisture conditions also induced greater swelling of the test blocks. The interaction of dose rate and moisture content reflects enhancement of the effect of the various dose rates

when the blocks were irradiated at saturated moisture conditions.

Conclusions

The results of these tests indicate that gamma radiation below 10^7 reps applied to ponderosa pine at the dose rates and moisture contents tested induces statistically significant changes in hygroscopicity and tangential swelling properties of the wood. However, the actual magnitude of the changes observed in these tests suggests that, from a practical standpoint, irradiated ponderosa pine sapwood will change in dimensions and absorb moisture in about the same manner as unirradiated pine.

PART II: DECAY SUSCEPTIBILITY

Test Procedure

A modified agar-block decay test was employed for this study. The decay chambers used were sterile Petri dishes containing 30 ml. of two per cent malt agar. They were inoculated by planting six mm. discs of mycelium from ten-day-old cultures of the test fungus *Lenzites trabea* (Pers. ex Fries) Fries (Madison isolate #617). After incubation for 14 days, mycelial mats had formed over the agar surface in each chamber.

Irradiated and control blocks for the decay tests were brought to approximately 50 per cent moisture content and sterilized in steam at atmospheric pressure for 30 minutes. They were then aseptically placed on 3 mm. glass *Z* rods over the mycelial mats in the decay chambers. The assembled decay chambers were incubated at 27°C. and 80 per cent relative humidity for four or nine weeks. After incubation, the blocks were removed from the Petri dishes, carefully brushed free of adhering mycelium, oven dried at 105°C., and weighed (± 0.005 gram). The loss in weight sustained by each block was determined as the difference between the final oven-dry weight and the initial calculated oven-dry weight, expressed as a per cent of the latter value.

Results

Tables 4 and 5 contain the average weight-loss data for the replicate blocks in each test. Means are given for all blocks treated at a given level of each variable. Mean squares from the analysis of variance for each test are presented in the second half of Table 6. The interactions shown to be significant may be more readily visualized by constructing "two-by-two tables" for the interacting variables (15). Such tables are not shown due to space limitations.

Discussion

In the four-week decay test, significantly different effects were induced at the three dose rates and moisture contents tested. As shown by the means in Table 4, gamma radiation applied at 0.6 megarep per hour, or to

Table 1.—HYGROSCOPICITY TEST—AVERAGE PER CENT MOISTURE CONTENT ACHIEVED BY IRRADIATED PONDEROSA PINE SAPWOOD BLOCKS AT 25°C AND 76 PER CENT RELATIVE HUMIDITY (CORRECTED FOR DRYING HYSTERESIS)

Total dose Reps	Dose rate: 0.2 Megarep per hour — Moisture content during irradiation: Oven dry	12% EMC	Saturated	0.4 Megarep per hour — Oven dry	12% EMC	Saturated	0.6 Megarep per hour — Oven dry	12% EMC	Saturated
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Controls	14.7	15.1	14.9	14.8	15.0	15.2	14.9	15.1	14.7
10^2	14.9	14.7	15.4	14.9	14.9	14.8	14.5	15.0	14.4
10^4	14.6	14.7	14.0	15.0	14.4	13.8	14.2	13.9	13.6
10^6	14.0	13.9	14.0	14.2	14.3	13.7	14.0	14.2	14.0
10^7	14.2	14.1	15.8	14.4	14.7	14.9	14.5	14.6	14.7

Means for the Levels of Each Variable[1]

Total dose Reps	Average moisture content in 27 blocks Per cent	Dose rate Megarep per hour	Average moisture content in 45 blocks Per cent	Moisture content during irradiation	Average moisture content in 45 blocks Per cent
Controls	14.8a	0.2	14.6a	Oven dry	14.6a
10^2	14.8a	.4	14.6a	12% EMC	14.7a
10^4	14.2b	.6	14.4a	Saturated	14.5a
10^6	14.0b				
10^7	14.6a				

[1]Means not followed by the same letter are significantly different at the one per cent level.

Table 2.—RADIAL SWELLING TEST—AVERAGE PER CENT RADIAL SWELLING OF IRRADIATED PONDEROSA PINE SAPWOOD BLOCKS

Total dose Reps	Dose rate: 0.2 Megarep per hour — Moisture content during irradiation: Oven dry	12% EMC	Saturated	0.4 Megarep per hour — Oven dry	12% EMC	Saturated	0.6 Megarep per hour — Oven dry	12% EMC	Saturated
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Controls	5.68	5.59	5.68	5.64	5.76	5.95	6.17	5.85	6.19
10^2	5.54	5.99	6.35	5.96	5.92	5.98	5.83	5.83	5.90
10^4	5.96	6.10	5.83	5.34	5.47	5.24	5.50	5.87	5.76
10^6	5.71	5.74	5.66	5.27	5.69	6.17	5.68	5.56	5.82
10^7	5.81	5.46	5.30	5.82	6.12	5.92	5.60	5.91	6.12

Means for the Levels of Each Variable[1]

Total dose Reps	Average per cent radial swelling in 27 blocks Per cent	Dose rate Megarep per hour per hour	Average per cent radial swelling in 45 blocks Per cent	Moisture content during irradiation	Average per cent radial swelling in 45 blocks Per cent
Controls	5.84a	0.2	5.76a	Oven dry	5.70a
10^2	5.92a	.4	5.75a	12% EMC	5.79a
10^4	5.67a	.6	5.84a	Saturated	5.86a
10^6	5.70a				
10^7	5.78a				

[1]Means not followed by the same letter are significantly different at the one per cent level.

Table 3.—TANGENTIAL SWELLING TEST—AVERAGE PER CENT TANGENTIAL SWELLING OF IRRADIATED PONDEROSA PINE SAPWOOD BLOCKS

Total dose Reps	Dose rate: 0.2 Megarep per hour — Moisture content during irradiation: Oven dry	12% EMC	Saturated	0.4 Megarep per hour — Oven dry	12% EMC	Saturated	0.6 Megarep per hour — Oven dry	12% EMC	Saturated
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Controls	6.72	6.94	7.44	7.02	6.82	7.17	6.94	6.82	7.03
10^2	7.17	7.01	7.49	7.13	7.17	7.30	7.21	7.15	7.15
10^4	6.89	6.60	7.44	6.60	6.84	7.16	6.56	6.67	6.83
10^6	6.90	7.04	6.96	7.10	6.75	7.30	6.45	6.72	6.49
10^7	6.86	6.83	7.06	6.78	7.04	7.08	6.75	6.80	7.14

Means for the Levels of Each Variable[1]

Total dose Reps	Average per cent tangential swelling in 27 blocks Per cent	Dose rate Megarep per hour	Average per cent tangential swelling in 45 blocks Per cent	Moisture content during irradiation	Average per cent tangential swelling in 45 blocks Per cent
Controls	6.99b	0.2	7.02a	Oven dry	6.97a
10^2	7.20a	.4	7.02a	12% EMC	6.98a
10^4	6.83c	.6	6.86b	Saturated	7.06b
10^6	6.89bc				
10^7	6.93bc				

[1]Means not followed by the same letter are significantly different at the one per cent level.

blocks saturated with moisture, significantly reduced the susceptibility of the test blocks to decay by *Lenzites trabea*.

In the nine-week decay test, all main effects and interactions were significant. As shown in Table 5, irradiation at 10^7 reps induced significantly greater susceptibility to decay in the test wood than that shown by controls or by blocks subjected to lower radiation doses. Radiation applied at 0.2 megarep per hour induced greater susceptibility to decay than when applied at higher rates. Radiation applied at each of the three moisture contents tested induced significant differences in the decay susceptibility of the test blocks. Those irradiated at 12 per cent moisture content were most susceptible to decay.

In both the four-week and nine-week decay tests, radiation doses below 10^6 reps reduced the susceptibility of the test blocks to decay, while larger total doses increased their decay susceptibility. These results confirm the generalization that doses in excess of 10^6 reps have the most pronounced degradative effects on wood (6). They also agree with the observations of Reese regarding the influence of increasing total doses on the susceptibility of cellulose to fungal cellulases (11).

The difference in significant factors at four and nine weeks in dose rate and moisture content are not contradictory, even though precision of the test is somewhat lower at nine weeks because of the larger experimental error. A dose rate of 0.6 megarep per hour, found to be a significant retarding factor at four weeks, remained a retarding factor at nine weeks. The rate at 0.2 megarep carried significance in that, at nine weeks, it became a factor that induced greater decay. The same analogy applies to moisture content: at four weeks, saturated conditions retarded decay, but at nine weeks, 12 per cent moisture content induced decay. The exception here is that oven-dry conditions caused relatively greater retardation in nine weeks.

In both decay tests, the significant first-order interactions involving moisture content reflect enhancement of total dose and dose rate effects when the wood was irradiated at saturated moisture conditions. In the interaction of total dose with dose rate, the highest level of each variable enhanced the effect of all levels of the other variable.

Table 4.—FOUR WEEK DECAY TEST—AVERAGE PER CENT LOSS IN WEIGHT OF IRRADIATED PONDEROSA PINE SAPWOOD BLOCKS DUE TO DECAY BY LENZITIES TRABEA

Total dose	Dose rate: 0.2 Megarep per hour			0.4 Megarep per hour			0.6 Megarep per hour		
	Moisture content during irradiation: Oven dry	12% EMC	Saturated	Oven dry	12% EMC	Saturated	Oven dry	12% EMC	Saturated
Reps	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Controls	11.0	11.3	10.0	10.3	8.8	10.9	10.5	9.8	10.0
10^2	10.4	11.5	10.0	10.4	10.5	11.4	10.1	10.8	9.3
10^4	11.4	10.9	10.3	11.0	10.0	10.8	10.3	10.5	8.0
10^6	10.9	11.0	10.0	9.7	10.6	10.6	10.9	10.7	6.6
10^7	12.4	11.6	9.9	9.9	11.9	11.3	12.0	11.6	7.2

Means for the Levels of Each Variable[1]

Total dose	Average weight loss in 36 blocks	Dose rate	Average weight loss in 60 blocks	Moisture content during irradiation	Average weight loss in 60 blocks
Reps	Per cent	Megarep per hour	Per cent		Per cent
Controls	10.3a	0.2	10.8a	Oven dry	10.7a
10^2	10.5a	.4	10.6a	12% EMC	10.8a
10^4	10.4a	.6	9.9b	Saturated	9.7b
10^6	10.1a				
10^7	10.9a				

[1]Means not followed by the same letter are significantly different at the one per cent level.

Table 5.—NINE WEEK DECAY TEST—AVERAGE PER CENT LOSS IN WEIGHT OF IRRADIATED PONDEROSA PINE SAPWOOD BLOCKS DUE TO DECAY BY LENZITIES TRABEA

Total dose	Dose rate: 0.2 Megarep per hour			0.4 Megarep per hour			0.6 Megarep per hour		
	Moisture content during irradiation: Oven dry	12% EMC	Saturated	Oven dry	12% EMC	Saturated	Oven dry	12% EMC	Saturated
Reps	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Controls	14.5	16.6	16.1	14.7	14.5	16.2	17.2	18.8	15.4
10^2	15.6	16.3	17.3	13.2	16.0	14.4	12.9	15.8	16.4
10^4	14.3	17.0	18.1	15.6	13.6	16.2	14.1	18.0	14.6
10^6	16.9	19.9	16.6	13.3	16.0	15.9	13.9	17.0	14.2
10^7	19.6	19.0	17.2	16.7	17.1	16.3	16.7	18.1	13.1

Means for the Levels of Each Variable[1]

Total dose	Average weight loss in 36 blocks	Dose rate	Average weight loss in 60 blocks	Moisture content during irradiation	Average weight loss in 60 blocks
Reps	Per cent	Megarep per hour	Per cent		Per cent
Controls	16.0a	0.2	17.0a	Oven dry	15.3a
10^2	15.3a	.4	15.4b	12% EMC	16.9b
10^4	15.7a	.6	15.7b	Saturated	15.9c
10^6	16.0a				
10^7	17.1b				

[1]Means not followed by the same letter are significantly different at the one per cent level.

Table 6.—MEAN SQUARES FROM THE ANALYSES OF VARIANCE FOR THE VARIOUS TESTS OF THE EFFECT OF GAMMA RADIATION ON PONDEROSA PINE SAPWOOD

Source of variation	Part I: Degrees of freedom	Hygroscopicity test mean squares	Radial swelling test mean squares	Tangential swelling test mean squares	Part II: Degrees of freedom	Four-week decay test test mean squares	Nine-week decay test mean squares
Main effects							
Total dose	3	3.95**	0.27	0.54**	4	3.07	15.14**
Dose rate	2	.47	.11	.39*	2	14.24**	47.13**
Moisture content	2	.09	.28	1.11**	2	20.58**	41.61**
Interactions							
Total dose X Dose rate	8	.19	.42	.07	8	.76	9.12**
Total dose X Moisture content	8	.70**	.10	.03	8	3.91*	10.50**
Dose rate X Moisture content	4	.39	.07	.22*	4	17.25**	13.26**
Total dose X Dose rate X Moisture content	16	.18	.15	.06	16	2.25	13.50**
Experiment error	90	.20	.17	[1].08	135	1.67	1.90
Coefficient of variation		3.07	7.33	4.06		12.46	8.80

*Indicates mean squares whose F test values showed significance at the five per cent level.
**Indicates mean squares whose F test values showed significance at the one per cent level.
[1]The degrees of freedom for this error mean square were reduced to 77 due to inadvertent loss of measurements on 11 blocks.

Conclusions

The results of these tests indicate that gamma radiation below 10^7 reps, applied at the dose rates and moisture contents studied, induced small but statistically significant changes in the decay susceptibility of ponderosa pine sapwood. The magnitude of these effects suggest that such wood does not present a markedly greater hazard of decay than unirradiated wood. In the design of future radiation experiments where maximum precision is required, however, the variables and interactions here shown to be significant will need to be considered. Most of the significant interactions encountered could probably be avoided in future work by irradiating blocks only at moisture contents well below saturation.

Addendum

An additional observation made in the course of this study may be of interest. Blocks that were irradiated oven dry or at 12 per cent moisture content showed a uniformly penetrating greenish-black discoloration, which increased with intensity of total dose. This color rapidly disappeared on heating or dipping in water, and slowly dissipated while standing at room temperature for several weeks. The color could be preserved for a longer, undetermined period by refrigeration. This discoloration was noted also in blocks subjected to high-energy cathode rays from a Van de Graaff accelerator. It is assumed that this observation reflects the "trapped ion" effect.

Literature Cited

1. Arthur, J. C. 1958. The effects of gamma radiation on cotton. Part II. Proposed mechanism of the effects of high energy gamma radiation on some of the molecular properties of purified cotton. Tex. Res. J. 38: 204–206.
2. Blouin, F. A., and J. C. Arthur. 1958. The effects of gamma radiation on cotton. Part I. Some of the properties of purified cotton irradiated in oxygen and nitrogen atmospheres. Tex. Res. J. 38: 198–204.
3. Charlesby, A. 1955. The degradation of cellulose by ionizing radiation. J. Polymer Sci. 15: 263–270.
4. Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11: 1–42.
5. Glegg, R. E., and Z. I. Kertesz. 1957. Effect of gamma-radiation on cellulose. J. Polymer Sci. 26: 289–297.
6. Lawton, E. J., W. D. Bellamy, R. E. Hungate, M. P. Bryant, and E. Hall. 1951. Some effects of high velocity electrons on wood. Science 113: 380–382.
7. Mark, H. 1957. Radiation chemistry and wood. Comp. Wood (India) 4: 1–8.
8. Mater, Jean. 1957. Chemical effects of high energy irradiation of wood. Forest Prod. J. 7: 208–209.
9. Paton, J. M., and R. F. S. Hearman. 1957. Effect of exposure to gamma rays on the hygroscopicity of sitka spruce wood. Nature 180. (4587): 651.
10. Pecjak, F. A., and K. H. Sun. 1955. Literature resources on the radiation effects of high polymers. American Inst. Chem. Eng., 25 West 45 St., New York 36, N. Y. Preprint 243.
11. Pew, J. C. 1952. The effect of high-energy cathode rays on spruce wood. Unpublished manuscript. Forest Prod. Lab., Madison, Wis.
12. Reese, E. T. 1956. A microbiological process report. Enzymatic hydrolysis of cellulose. Appl. Microbiol. 4: 39–45.
13. Saeman, J. F., M. A. Millett, and E. J. Lawton. 1952. Effect of high energy cathode rays on cellulose. Ind. Eng. Chem. 44: 2848–2852.
14. Sun, K. H. 1954. Effect of atomic radiation on high polymers. Modern Plastics 32: 141–144, 146, 148, 150, 229, 230, 231–233, 236, 237.
15. Snedecor, G. W. 1948. Statistical methods. Iowa State College Press, Ames, Ia. 485p.

Tension Wood in Cottonwood . . .

ITS EFFECT ON DENSITY, TOUGHNESS, AND COMPRESSION[1]

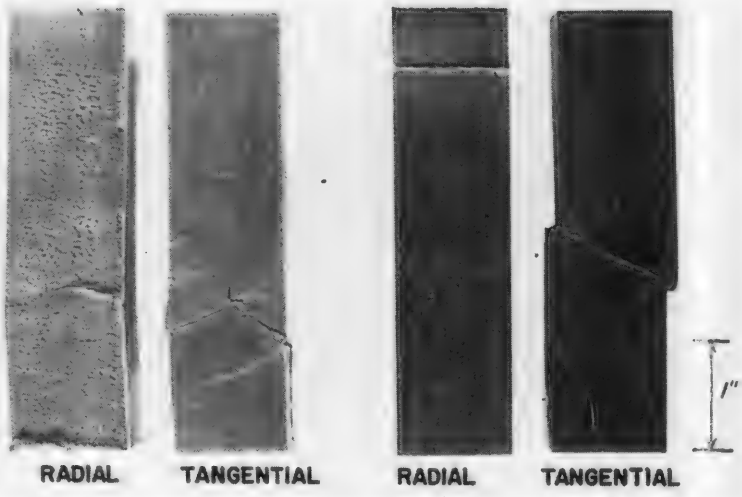


Fig. 1.—Left: bending and crushing failures typical of tension wood compression-parallel-to-the-grain specimens. Right: shear failures found in normal wood compression-parallel-to-the grain specimens.

L. E. Lassen

Division of Timber Growth and Utilization Relations, Forest Products Laboratory[2], Forest Service, U.S. Department of Agriculture

Density, toughness, crushing strength, and modulus of elasticity were compared for normal and tension wood. Conclusions apply specifically to eastern cottonwood trees used.

EASTERN COTTONWOOD, because of its rapid growth and abundance on lands unsuited for agriculture, is one of the most important species in the Midwest. Based on evaluation by means of standard log grades, the U. S. Forest Survey[3] found cottonwood stems to be of considerably higher quality than the stems of most other Midwest species. The increasing use of this species has resulted in considerable interest in the presence of tension wood as it relates to various manufacturing problems.

Tension wood is a form of reaction wood commonly found on the upper side of branches and leaning stems of angiosperms. It is thought that its function is to restore or try to maintain the tree stem in a vertical position and to strengthen and support the branch. The distinguishing microscopical characteristic of tension wood is the development of a "gelatinous" ring or layer as part of the secondary wall of the wood fiber. The greatest concentration of gelatinous fibers in cottonwood has been found by Kaeiser

[1] A 1958 Wood Award entry submitted while the author was a graduate student at Iowa State College, Ames. Journal Paper No. J-3418 of the Iowa Agricultural and Home Economics Experiment Station, Ames.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

The Author: Laurence Lassen holds a BS in forestry and an MS in wood technology from Iowa State College, Ames. He was a graduate assistant at Iowa State, and is now a wood technologist at the US FPL.

[3] The Forest Survey of Iowa listed 172 million bd. ft., or 29 per cent of the cottonwood of Iowa to be in log grade 1. Central States Forest Experiment Station. 1956. Iowa forest statistics. For. Survey Release 20.

and Pillow (1)[4] to occur on the upper side of the leaning stem at breast height. In addition, they found that the number of gelatinous fibers on the upper side of the leaning stem increased with increasing degree of lean.

Eccentricity of growth related to tension wood development has been found by some workers; however, it appears that eccentric growth varies not only among species, but among individual trees as well. Wahlgren (2) found no evidence of eccentricity associated with tension wood in cottonwood.

The presence of tension wood is definitely noticeable to the naked eye in several species of wood. Probably the most obvious single characteristic of tension wood is the abundance of projecting fibers on sawn surfaces, which give a woolly or fuzzy appearance to the wood. Machining of tension wood is difficult and may present serious problems. When sawing sugar maple containing tension wood, Marra (3) found that the wood "worked" and "squirmed" as latent stresses were relieved. The stresses were so great that a buckling action between the saw blade and the ripping guide produced a "pinch," which made further sawing impossible. Clean cuts were hard to make when gelatinous fibers were present in large amounts, because the fibers were torn out in groups that remained attached at one end. These masses of long fibers were observed by Dadswell (4) to clog the saw teeth and badly overheat the saw.

Seasoning wood containing gelatinous fibers, so that defects attributable to tension wood are kept at a minimum, is a major problem. Clark (5) studied the effect of the excessive longitudinal shrinkage of tension wood in the seasoning of cottonwood. He found that bowing in kiln dried boards containing tension wood was greater than in boards of normal wood. In boards from the upper side of the tree, the severity of bowing showed an inverse relationship to the distance of the board from the bark. Collapse seems to be closely associated with the presence of tension wood, particularly in cottonwood. In most instances, collapse can be removed and the wood restored to its original condition by standard steaming methods or by boiling in water. Wardrop and Dadswell (6), however, were unable to "recover" specimens of collapsed eucalyptus containing tension wood by these methods.

Most workers agree that tension wood has a higher specific gravity than normal wood. Wahlgren (2), however, noted that the specific gravity of tension wood in eastern cottonwood was lower than that of normal wood.

The strength properties of tension wood have been investigated to a rather limited extent. Clarke's (7) toughness tests on beech showed that gelatinous fibers do not decrease toughness values. In comparing tension wood and normal wood specimens, the tension wood had a lower mean specific gravity but a higher mean toughness value than the normal wood. Working with Australian species, Dadswell and Wardop (8) found tension wood to be, if anything, less tough than normal wood.

Several authors agree that tension wood has lower strength properties than normal wood in compression parallel to the grain. Clarke (9), working with specimens of beech of roughly the same specific gravity, found some with rather weak compressive strength. Examination showed the weak specimens to contain gelatinous fibers while the strong specimens were free from tension wood. Later, as the specimens were tested to complete failure, the majority of tension wood specimens failed by buckling, whereas the majority of normal specimens failed by shear.

The purpose of this investigation is to study the effect of tension wood on the specific gravity, toughness, and endwise compressive strength of eastern cottonwood. The toughness test is used largely as an over-all estimate of the quality of wood for critical uses. The test of compression parallel to the grain is a measure of the endwise compression of the wood, and is related to the use of wood as short posts or props in many types of construction.

Procedure

Selection of Specimens: To eliminate unnecessary sources of variation, standards were established for the selection of cottonwood trees to be used. Five trees were selected, with a dominant or codominant crown class, from an even-aged stand of uniform site index. A minimum diameter at breast height of 15 inches and a lean of 10 degrees were required. The 10-degree lean was thought to be more than sufficient to assure development of gelatinous fibers. The upper side of lean was carefully marked at breast height before the selected trees were felled. The test specimens were selected from 2.5-foot bolts cut from the stem so that breast height (4.5 feet) was the center point of the bolt.

So that tangenitally matched comparisons could be made, three annual rings were arbitrarily chosen in each bolt. Groups consisting of three specimens were marked off with each selected annual ring as the basis of orientation. Six sticks with a common annual ring, three from the upper and three from the lower side of the leaning stem, were cut from each of the annual rings chosen. This gave a total of 18 sticks from each bolt (tree), nine from each of the opposing sides of lean. By means of a modified random selection system, the kind of strength test to be performed on each specimen was determined. The test designation of the middle stick in each tangentially matched three-stick group always differed from the test designation of the two adjacent sticks.

Upon completion of drying, each stick was cut in two with the lower half receiving a test designation different from that of the upper half. Each bolt (tree) then provided a total of 36 specimens, 18 from opposing sides of the lean, with an equal number designated for each type of test. This gave a total number of 90 specimens each for the toughness and the compression-parallel-to-the-grain tests. Each specimen was marked to identify its original position within the bolt. Inspection prior to testing was made to note defects such as checks, shake, and grain deviation.

Conditioning: The sample bolts from the five trees were end-coated immediately after they were cut to prevent rapid drying of end surfaces with resultant end checking. After the bolts had been cut into roughly dimensioned sticks, the sticks were allowed to air season for approximately two months. The sticks were then placed in a controlled temperature-humidity chamber for one month and dried to an average moisture content of 6.4 per cent. A very mild drying schedule was used to avoid development of longitudinal checking and collapse that is characteristic of tension wood. Case-hardening and shell-and-core moisture gradient tests indicated a satisfactory removal of drying stresses.

All sticks were machined to a standard size, cut in halves, and placed in a controlled temperature-humidity room at the U. S. Forest Products Laboratory, Madison. The constant temperature of 80° F. and relative humidity of 65 per cent were used in an attempt to bring the specimens to a moisture content as near 12 per cent as possible. The specimens came to equilibrium at an average moisture content of 10.8 per cent with a variation of less than 1 per cent moisture content. The specimens were then machined to final test size. Moisture content determinations were made on all test specimens immediately following strength tests. It was noted that

[4] Numbers in parentheses refer to the Literature Cited at the end of this paper.

tension wood specimens had a lower average moisture content than did the normal wood specimens.

Testing

Toughness Testing: The toughness tests were made on specimens 0.79 x 0.79 x 11 inches (2 x 2 x 28 centimeter) in accordance with the standard procedure prescribed by ASTM tests for small clear timber specimens (D 143–52). The cross-sectional dimensions at the center and the length of the specimens were measured to the nearest 0.001 inch. Each specimen was marked on the tangential face toward the pith to insure a uniform point of load application. The toughness tests were performed on the Forest Products Laboratory Toughness Testing Machine.

Each specimen was weighed before testing, and immediately after testing a two inch piece was cut near the point of failure and weighed for use in moisture content and specific gravity determinations.

Compression Testing: The compression parallel to the grain tests followed the Secondary Method described in ASTM tests for small clear timber specimens (D 143–52). The Secondary Method uses 1 by 1 by 4 inch specimens instead of 2 by 2 by 8 inch Primary Method specimens. The use of the smaller specimen was necessary to enable the required number of samples to be cut free from defect. The testing procedure for the Secondary Method is similar to the Primary Method. Measurements of the specimens were made to the nearest 0.001 inch, and they were weighed prior to testing for subsequent determination of moisture content and specific gravity. After it was tested, the entire specimen was used for both moisture content and specific gravity determinations.

The load was applied continuously throughout the test at the rate of 0.012 inch per minute. After the maximum load had been reached, the rate of load was increased to delineate the planes of failure.

Testing was done at the U. S. Forest Products Laboratory on a static testing machine adapted for the use of a Lamb's Roller Extensometer, which is a device fitted to the radial sides of the test specimen. It enables deflection-compression curves to be plotted directly through the use of mirrors and reflected light (Fig. 2).

Specific Gravity Determinations: Specific gravity is generally recognized as the most important single characteristic available to use as an index of strength properties, and has been found to be more closely related to endwise compressive strength than to toughness. For these reasons, the specific gravity, based on oven-dry weight and volume at the time of test, of each specimen was computed according to the following formula:

$$\text{Specific gravity (at time of test)} = \frac{0.061 \times \text{weight in grams}}{\text{volume in cubic inches}}$$

Results and Discussions

Growth Eccentricity: Measurements from the pith to the bark were made at opposing points in the direction of maximum lean and at opposing points at right angles to the leaning direction of the tree. No indication of growth eccentricity was noted on the upper side of lean despite the presence of tension wood.

Machining: The difficulty in sawing the upper side of the green bolts into sticks, and the fuzzy surface of the exposed wood when the sticks were machined under green or dry conditions, were considered indicative of gelatinous fibers in the wood. A band saw equipped with a 1-inch blade was used to saw the bolts into sticks, but proved to be inadequate. It was impossible to make a straight cut in the tension wood halves because of the release of internal stresses. A wedge was driven into the saw cut to prevent the wood from closing behind the blade and stopping the saw. Despite careful handling, feeding the wood into the saw slowly, and the use of a wedge, the saw blade was broken. In contrast to the above difficulties, the normal wood halves presented no difficulties in sawing. Bundles of torn fibers were found protruding from the surfaces of all tension wood sticks. Bowing concavely on the bark side was noticed almost immediately in some of the tension wood sticks as internal stresses were relieved.

Final machining of specimens was done at approximately 10 per cent moisture content with a special hollow-ground circular saw. The saw was changed nine times in the process of cutting 180 specimens. The rapid "dulling" of the hollow-ground circular saw was not expected and is diffiult to explain. Because no attempt was made to saw the tension wood and normal wood specimens as separate groups, it is impossible to say whether the tension wood specimens "dulled" the saw faster than the normal wood specimens. It is thought that the presence of tension wood was a factor in the rapid "dulling" of the saw, and is likely related to the fact that the gelatinous fibers do not sever easily, and thereby result in projecting fibers that pinch and clog the saw. This pinching and clogging may in turn cause overheating and may contribute to removing the set in the saw. "Dulling," then, is probably caused by the loss of set rather than a wearing of the cutting edges.

Specific Gravity: Specific gravity values computed separately for toughness and compression-parallel-to-the-grain specimens indicated a significant difference (at the 1 per cent level) in specific gravity between trees, upper and lower sides of the trees with respect to lean, and positions with respect to distance from the bark.

Averages for each tree showed the tension wood side of the tree to have a higher specific gravity and significantly so (at the 1 per cent level) in trees 2 and 4. There was also a definite trend, although not generally significant, for tension wood to have a higher specific gravity than normal wood in the bark, middle, and pith position within the tree.

Considering both sides of lean, specific gravity followed a variable pattern in relation to the distance of the wood from the pith. In most instances, the specific gravity increased away from the pith and then decreased near the bark.

Because the greatest development of gelatinous fibers has been found to take place on the upper side of lean at breast height (4.5 ft.), one may conclude that the increase in specific gravity of the upper side is due to the presence of gelatinous fibers. The development of the gelatinous layer in the secondary cell wall occurs after differentiation and enlargement of the primary wall, and consequently most workers have found little if any difference in cell diameter and length between the gelatinous and normal fiber. The cell wall of the tension wood fiber, however, has generally been found to be thicker than normal because of the thickened gelatinous layer. The pore or vessel diameter and the number of vessels have been found to be less in tension wood. For a given volume of wood, therefore, tension wood with its higher percentage of fibers and thicker fiber walls should have a higher specific gravity than wood composed of normal fiber.

Maximum concentration of gelatinous fibers has been found by Kreiser and Pillow (1) to occur closest to the bark and diminishes toward the pith. In this study, the trend of specific gravity values for both normal and tension wood was for the center position, with respect to the pith and bark, to have the highest value. This would indicate that there are other factors in addition to gelatinous fibers that control specific gravity.

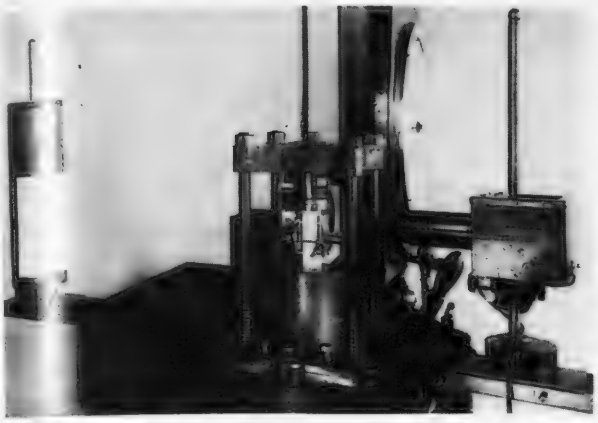


Fig. 2.—Testing apparatus for compression parallel to the grain, adapted for use with Lamb's Roller Extensometer.

Table 1.—AVERAGE VALUES[1] OF SPECIFIC GRAVITY, TOUGHNESS AND ENDWISE COMPRESSION FOR TENSION WOOD AND NORMAL WOOD FROM FIVE EASTERN COTTONWOOD TREES

	Specific gravity (toughness)	Specific gravity (endwise compression)	Toughness in-lbs.	Compression parallel to the grain: Maximum crushing strength psi	Compression parallel to the grain: Modulus of elasticity 1000 psi
Tree 1					
normal wood	0.386	0.393	139.0	4,826	1,647
tension wood	.407	.401	309.9	4,447	1,752
Tree 2					
normal wood	.464	.462	215.1	5,568	1,963
tension wood	.494	.501	462.7	5,291	2,023
Tree 3					
normal tree	.367	.381	146.9	4,116	1,280
tension wood	.382	.382	240.9	3,815	1,390
Tree 4					
normal wood	.454	.449	185.8	5,206	1,714
tension wood	.488	.484	471.9	5,319	2,085
Tree 5					
normal wood	.452	.448	149.4	5,600	1,890
tension wood	.462	.451	390.4	4,650	1,803

[1]These figures are average values from 9 specimens; 3 tangentially matched specimens from near the bark, 3 from near the pith, and 3 from a middle position.

Toughness Results: The toughness values were significantly greater (at the 1 per cent level) for specimens from the upper side as compared with specimens from the lower side of lean (Table 1), and increased in positions toward the bark. Failures in normal wood appeared to be more brash than failures in the tension wood specimens.

Regression analysis indicated that toughness increased with an increase in specific gravity at a greater rate for tension wood than for normal wood (Fig. 3).

Toughness has been reported by Clarke (10) to depend largely on the properties of the primary cell wall and the middle lamella. Chemical analyses have shown that the degree of lignification of the primary cell wall and the middle lamella is approximately the same in tension wood and normal wood fibers. The basic differences between the tension wood and normal wood fiber seems to be the greater size and higher cellulosic content of the gelatinous layer of the secondary cell wall (11). The greater toughness of tension wood over normal wood can be understood if the difference in toughness depends more on the properties of the secondary wall than on the primary wall and middle lamella. Clarke (7) has demonstrated that tension wood has a greater strength in tension parallel to the grain, so perhaps the greater toughness of tension wood can be attributed to the tensile strength of the gelatinous secondary wall. There is also the possibility that the higher cellulosic content of the gelatinous layer will result in increased plasticity, thus increasing the ability of the wood to absorb energy.

It was noted that toughness increased from the pith toward the bark for both tension wood and normal wood; however, the toughness of tension wood increased at a greater rate. Toughness probably is not influenced so much by specific gravity as by gelatinous fiber development.

Endwise-compression Results: Maximum crushing strength values showed normal wood to be stronger than tension wood (Table 1). Trees 1, 3, and 5 had significantly higher values (at the 1 per cent level) in the normal wood. The correlation coefficients of 0.883 and 0.807 for the upper and lower sides of lean, respectively, indicated a very high degree of correlation between specific gravity and maximum crushing strength (Fig. 4). The close correlations between specific gravity and endwise compression strength would lead to the supposition that tension wood with its higher specific gravity would have correspondingly higher compressive strength values than normal wood. This, however, is not the case. The endwise compressive strength is probably dependent largely on the chemical composition and combined strength of the primary and secondary cell walls. In normal wood, increasing specific gravity is usually associated with thicker fiber walls and a higher concentration of lignin, which adds strength. Tension wood's increases in specific gravity are likely associated with a thicker gelatinous layer in the secondary cell wall. The gelatinous layer is constituted largely of cellulose, and appears to be very loosely attached to the remainder of the cell wall, and hence adds little to compressive strength.

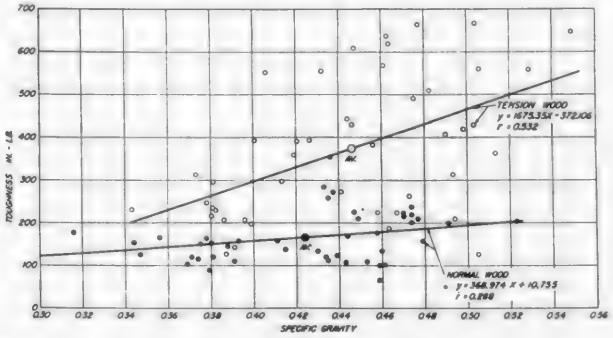


Fig. 3.—Regression of toughness on specific gravity for normal wood and tension wood in eastern cottonwood.

Fiber stress at the proportional limit was essentially the same for tension wood and normal wood. Regression analysis of the deflection at the proportional limit showed a very slight increase in deflection with increasing specific gravity for tension wood. Normal wood, however, decreased in deflection with increasing specific gravity.

The modulus of elasticity, which is a measure of stiffness, followed the specific gravity pattern, increasing and then decreasing from the pith toward the bark in both tension and normal wood. Tension wood had higher modulus of elasticity values for specimens with a low specific gravity, while normal wood had the higher values for specimens with a high specific gravity. Regression analysis (Fig. 5) indicated that the normal wood side was influenced to a greater extent by specific gravity than was the tension wood side. As the modulus of elasticity is de-

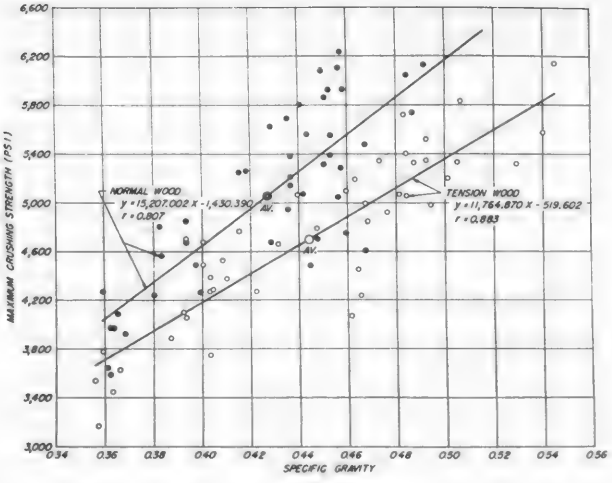


Fig. 4.—Regression of maximum crushing strength on specific gravity for normal wood and tension wood in eastern cottonwood.

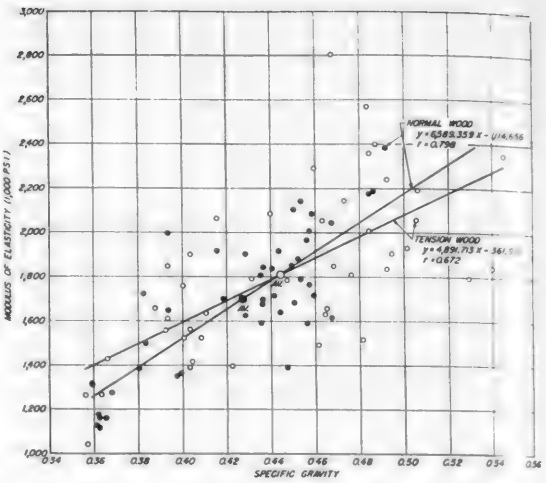


Fig. 5.—Regression of modulus of elasticity on specific gravity for normal wood and tension wood in eastern cottonwood.

rived from the relationship of fiber stress and deflection at the proportional limit, regression analyses and correlation coefficients of these factors on specific gravity were computed. As the specific gravity of normal wood increased, the fiber stress at the proportional limit also increased, but the deflection at the proportional limit decreased. This indicates that normal wood becomes stiffer as well as stronger with increasing specific gravity. The fiber stress at the proportional limit increased with increasing specific gravity in tension wood, but the deflection also increased slightly. Increasing deflection with increasing specific gravity is probably because a large part of the specific gravity increase is accounted for by the gelatinous cell wall layer, which adds little to strength and increases the flexibility of the wood. This accounts for the higher modulus of elasticity found in normal wood specimens at increasing specific gravity values.

The failure in each compression-parallel-to-the-grain specimen was examined for classification as to type of failure. It was noted that crushing failures were the most common type in both tension wood and normal wood; however, shear failures also occurred frequently in the normal wood. Tension wood specimens often exhibited a bending and crushing type failure but seldom had a shear failure. The shear strength of tension wood is higher than normal wood, possibly because the tension wood fiber has the ability to give under load and is able to absorb more stress (12). Fig. 1 shows examples of bending and crushing type failures in tension wood specimens and shear failure in normal wood specimens. The fuzzy radial surface of the tension wood specimen is an indication of the presence of gelatinous fibers.

Conclusions

1. Machining of tension wood is difficult and in some cases almost impossible without special equipment. Tension wood is possibly a factor in the rapid "dulling" of saws where pinching and clogging results in overheating and loss of set.

2. When exposed to equal conditions of temperature and relative humidity, tension wood will increase in moisture content at a slower rate than normal wood.

3. Tension wood has a higher average specific gravity than normal wood.

4. Compression-parallel-to-the-grain strength values are much more closely associated with specific gravity than are toughness values.

5. The toughness values of tension wood are much higher than normal wood and increase from the pith toward the bark. An analysis of variance indicates that toughness depends less on specific gravity than on position. Since the amount of gelatinous fiber development is greatest near the bark, high toughness values are probably closely correlated with the number of gelatinous fibers present.

6. Normal wood is stronger in compression paralled to the grain than is tension wood, despite a lower specific gravity.

7. The average modulus of elasticity (stiffness) of tension wood is slightly higher than that of normal wood. With increasing specific gravity, however, normal wood tends to become stiffer than tension wood.

Literature Cited

1. Kaeiser, Margaret, and M. Y. Pillow. 1955. Tension wood in eastern cottonwood. Central States For. Exp. Sta. Tech. Paper No. 149.

2. Wahlgren, H. E. 1957. Effect of tension wood in a leaning eastern cottonwood. Forest Prod. J. VII (6) 214.

3. Marra, A. A. 1942. Characteristics of tension wood in hard maple. (*Acer saccharum* Marsh.). Unpublished M.S. Thesis, Syracuse, N. Y. N. Y. State College of Forestry Library.

4. Dadswell, H. E. 1945. Timbers of the New Guinea region. Tropical Woods 52:1–11.

5. Clark, W. P. 1958. Effects of tension wood on seasoning and machining of eastern cottonwood. Forest Prod. J. VIII (3):109.

6. Wardrop, A. B., and H. E. Dadswell. 1948. The nature of reaction wood. The structure and properties of tension wood fibers. Austr. Jour. of Scientific Research, Series B, Biological Sciences 1:3–16.

7. Clarke, S. H. 1937. The distribution, structure, and properties of tension wood in beech (*Fagus sylvatica* L.). Forestry 11:85–91.

8. Dadswell, H. E., A. B. Wadrop. 1949. What is reaction wood? Austr. Forestry 13:22–33.

9. Clarke, S. H. 1936. The influence of cell-wall composition on the physical properties of beech wood. Forestry 10:143–148.

10. Clarke, S. H. 1935. Recent work on the relation between anatomical structure and mechanical strength in English ash (*Fraxinus excelsior* L.) Forestry 9:132–138.

11. Jayme, G., and M. Harders–Steinhäuser. 1950. über die chemische Zusammensetzung des Zugholzes in einer Pappelholz. (Chemical composition of tension wood in poplar.) Papier, Darmstadt 4:104–113. (Original not available for examination; abstracted in For. Abst. 14:334. 1953.

12. Haskell, H. H. 1958. Strength properties of tension wood and typical wood in a leaning eastern cottonwood tree using cross-lap and block-shear glue test specimens. Forest Prod. J VIII (1):17.

RECOMMENDATIONS OF THE MADISON CONFERENCE ON

Fundamental Research In Wood Drying[1]

R. L. YOUNGS
Technologist, Forest Products Laboratory,[2] Forest Service, U. S. Department of Agriculture

We still dry wood by simply adding heat to evaporate water. This conference, held in October of 1957, laid the groundwork for increasing our knowledge of the fundamental relationships between wood and water.

Vibration studies may lead to methods of improving the movement of liquids and vapors through wood.

THE SEASONING OF WOOD INVOLVES many and varied practical problems. This is true whether we speak of air drying, conventional kiln drying, or one of the many so-called "special" methods of wood drying. This is also true whether we speak of drying lumber, drying veneer, drying chips, or drying sawdust. While present drying procedures generally can produce lumber uniform in moisture content and free of drying stresses, footage losses due to seasoning degrade are not being reduced, and often the drying time is excessively long.

All these practical problems demand practical and workable solutions. It has become an axiom of our age, however, that practical problems frequently are best solved as a result of apparently impractical but thoughtfully carried-out research. Such research serves the vital function of contributing to a reservoir of fundamental information on which to draw in finding new approaches and solutions to practical problems. A reservoir of this type is essential to technical progress in any field, including the field of wood drying.

It has become apparent to many who have critically reviewed the present status of the field of wood drying that, while substantial improvements have been made in kiln design, kiln operation, drying schedules, methods of stacking lumber for kiln drying, and methods of handling lumber for air drying, relatively little progress has been made in improving fundamental processes and procedures for wood drying. We still dry most of our wood by supplying heat and evaporating water, just as we have been doing for many years, without really learning much about the fundamental relationships between water and wood.

The fact that we have been operating in this manner for so long disturbs a great many people who have a real concern for the future of the wood industries. Wood must be dried, and better and cheaper than ever in the past, yet we are fast depleting the fund of fundamental information left to us by such pioneers as H. D. Tiemann.

It was just such a concern that led to this conference on fundamental research in wood drying. Forty men from laboratories, universities, and industry met for two days to discuss the status of wood drying research and to express thoughts and ideas for possible approaches of a fundamental nature that might lead to really significant basic advances in the practice of wood drying. Participation in the conference was not confined to persons whose primary interest is wood drying, since it was felt that the experience of leading figures in current work on the drying of other materials and the use of other energy sources than those customarily applied to wood would broaden the basis of consideration of the problem. So far as possible, the ideas brought out were not limited by existing concepts of practicality. It was recognized at the outset of the conference that approaches lacking even a remote appearance of practicality at the time might very well be the key to significant progress in the near future by leading to solutions for present drying problems that cannot even be visualized now.

Seven Recommendations:

At the conclusion of the conference, the conferees went on record as favoring seven general recommendations for fundamental research in the field of wood drying.[3] These recommenda-

The Author: Robert Youngs holds a BS from New York State College of Forestry, an MS from the University of Michigan, and a PhD from Yale University. He has been at the US FPL since 1951, and was the 1957 Wood Award winner.

[1] Held at the U. S. Forest Products Laboratory, Madison, Wis., October 17–18, 1957.
[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] The recommendations were originally drafted by a committee consisting of A. S. Gregory, Weyerhaeuser Timber Co., Chairman; E. L. Ellwood, California Forest Products Laboratory; C. Skaar, State University of New York College of Forestry; and A. J. Stamm, U. S. Forest Products Laboratory.

tions will be reviewed here with some insight given into the reasoning behind them.

The fields of investigation recommended as being particularly promising in terms of a fundamental approach to wood drying were as follows:

1. Factors affecting the permeability of wood to liquids, vapors, and solutions, and methods of improving permeability.
2. Mechanisms by which water is held in wood and by which water moves through wood.
3. Development and application of techniques for evaluating the stress-strain behavior of wood under drying conditions.
4. Mechanical properties of wood related to drying behavior as they are affected by drying conditions.
5. Heat transfer and boundary layer effects.
6. Chemical methods of controlling the drying process.
7. Application of "unconventional" forms of energy to the drying of wood.

It was recommended that investigations aimed at solving problems related to the permeability of wood to moisture and the mechanisim of moisture movement would be likely to yield the greatest ultimate gain, though it is recognized that this is a very complex area of investigation. Not enough is known about the fundamental relationship between wood and moisture, the forces of attraction that are responsible for the hygroscopic nature of wood. Not enough is known about the mechanisms that control the rate at which moisture moves through wood and the relationship of such mechanisms to the wood structure through which the moisture must move.

First, with respect to the permeability of wood, strong interest was expressed in fundamental investigation of the effectiveness of pits and pit-membrane openings as avenues for movement of liquids, vapors, and solutions through wood. Chemical methods of treating wood to improve the permeability of pit structures have shown some promise. Such methods might be effective in releasing aspirated pits or perhaps in completely removing pit structures. This is not a new idea. Persons concerned with wood drying and wood preservation have been aware for years of the potential benefits of unobstructed pit areas. Vibration methods might be employed to accomplish physically somewhat the same objective by releasing aspirated pits or otherwise opening up the pit-membrane structure.

Another possible approach would be through the use of some form of radiant energy, such as gamma rays, to improve permeability. A striking characteristic of gamma rays is their immense penetrating power, and, while little is known of their effect on wood, it is conceivable that their penetration could effect a substantial improvement in permeability.

There may be no real reason, on the other hand, why treatments to improve penetrability need to wait until the tree has been cut and the lumber produced. Physiological methods of improving permeability during tree growth might be developed as a result of investigations into factors that influence pit formation and structure and the determination of methods of modifying such factors to influence pit aspiration and pit-membrane structure.

Closely related to this is the suggestion that the science of genetics might be utilized to breed varieties with permeable wood. For example, it has been widely observed that the heartwood of coast-grown Douglas-fir is much easier to penetrate with preservatives than is the heartwood of mountain-grown Douglas-fir. Any method of improving the permeability of wood could conceivably reduce drying time and make the wood easier to treat with preservatives or other chemicals.

How Water is Held

Second, and closely related to the recommendation for work on permeability of wood, is the problem of investigating the mechanisms by which water is held in wood and by which water moves through wood. The drying of wood involves a combination of free liquid flow and water diffusion through the microscopically visible capillary structure together with bound-water diffusion through the solid wood substance.

The conferees went on record as favoring research within this field aimed specifically at developing easier and more effective methods of determining moisture gradients. A moisture gradient in drying gives important clues to the mechanism of moisture movement by indicating, for example, departures from the assumed limiting diffusion in material of lumber thickness.

An effective nondestructive method of evaluating moisture gradients would permit studying more complex cases of moisture distribution than have heretofore been investigated, and would facilitate the investigation of relationships between moisture gradients, temperature gradients, and stress gradients.

Electrical conductivity measurements offer a nondestructive method of determining moisture content below the fiber-saturation point within about ±2 per cent. This is not accurate enough, however, which leads to the observation that more fundamental information on the electrical properties of wood would be of value, both in this connection and in many other applications.

Steady-state diffusion studies might well yield information applicable to the moisture-gradient problem. The use of radioactive emissions was suggested as a means of measuring moisture gradients. Any currently known methods of measuring the intensity of such emissions in this application would probably be destructive, but might lead to a nondestructive method.

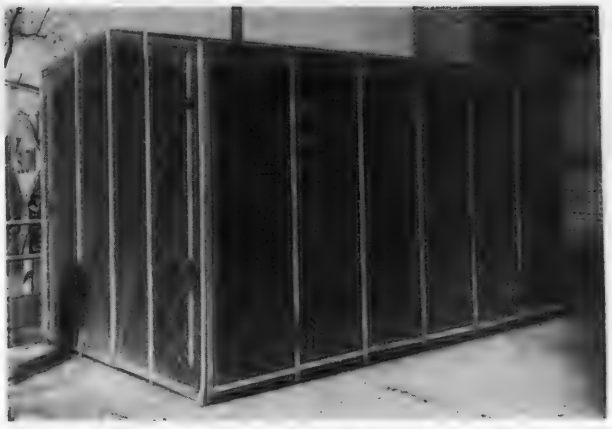
The next concern of the conference was in the field of investigation that might be designated as mechanical properties and behavior as related to drying. This is a field that has been receiving some attention at the U. S. Forest Products Laboratory and a few other places in recent years in an attempt to establish a substantial basis on which to make improvements in drying schedules.

Strain Behavior During Drying

The third recommendation of the conference calls for research aimed at improving techniques for evaluating the stress-strain behavior of drying wood. Experimental work has included many such measurements, based generally on the elastic recovery of slices cut from the wood in the perpendicular-to-grain direction at various stages of drying. While such determinations have yielded considerable valuable information about strain behavior during drying, it was recognized by the conferees that refinements could be made, or completely different approaches tried, to give a more complete and more accurate stress-strain evaluation.

An X-ray technique based on fringe patterns of space lattices has been used to determine strains in some materials. Such a technique, coupled with knowledge of interfibrillar space relationships under various moisture-content and strain conditions, might also be applicable to determination of internal strains in wood. There may be possibilities in the application of gamma ray techniques. Also, it has been shown that wood exhibits piezo-electricity—electricity produced as a result of mechanical deformation—though the electricity thus produced is slight and is likely to be difficult to measure because of the high natural electrical resistance of wood. Several means of measuring strains in wood, including internal metalectric gages,

Pit membrane structure (here enlarged to 1,000 diameters) is fundamental to passage of water and preservatives.



The harnessing of solar energy for drying lumber is being studied in experimental kilns like this one at the FPL.

seem to be within the realm of possibility, but much work needs to be done in evaluating them and in working out practicable techniques.

Any effective technique for following the mechanical behavior of drying wood will not be of significant benefit, however, until we know more about the relationship between stress, strain, and wood failure under the conditions of temperature, moisture content, and time likely to be encountered in drying. Most of the strain that occurs in wood as it dries is plastic and, as such, not directly associated with stress or potential energy.

The fourth recommendation of the conference, then, calls for continuation and expansion of the present work on the mechanical properties related to the drying of wood under various conditions of moisture, temperature, time, and loading. This should apply both to whole wood of various types and to wood elements and microstructure of wood. It has been established, for example, that some woods show pronounced differences in shrinkage between rays and adjoining longitudinal elements. The structural differences between such tissues indicate that there are differences in mechanical properties as well. The shear stresses that occur at the rays and the differences in strength between ray tissue and longitudinal tissue may play a significant part in the start of checking that occurs in drying, generally in association with the wood rays.

In connection with such work, there would be need for developing microtechniques suitable for studying the mechanical behavior of wood elements and the microstructure of wood. It was suggested that the work on the relationship of mechanical properties to temperature, moisture content, and time include investigation of the effects of these variables on the rheological characteristics, creep and stress relaxation.

The results, it was pointed out, should be correlated with work on strain analysis during drying along the lines already being followed in fundamental seasoning research at the U. S. Forest Products Laboratory. Further, it should not be confined to drying-stress development, but should include investigation of stress relief as well. It was also suggested that an investigation into the fundamental causes of differences between hardwoods and softwoods in their drying characteristics might shed considerable light on the relationship between drying behavior and wood structure, mechanical properties, and moisture-movement characteristics.

The fifth recommendation of the conference calls for the evaluation of heat-transfer and boundary-layer effects. Most wood drying, as it is currently practiced, involves heat transfer by convection from heated air moving across the surfaces of the wood. Although significant reductions in drying time have been accomplished by increasing the velocity of the air moving between the layers of lumber, there has been very little basic research on the effects of such variables as velocity, humidity, temperature, and turbulence of the air and moisture content and roughness of the wood surface on heat transfer by convection. Basic information on the effects of such variables would be of considerable value in increasing the effectiveness of drying equipment now in use, as well as in developing improved drying techniques.

It was also suggested that the effects on heat transfer, by radiation, of such variables as temperature of the radiator, temperature of the wood, and condition of the wood surface be investigated. Much veneer is dried by periodic application and withdrawal of heated platens, which provide heating by direct contact. The effects of contact time, removal time, platen temperature, and wood moisture content should be investigated.

High Frequency Heating

It was brought out that there has been some interest shown in dielectric heating by high-frequency electrical energy, since this offers a source of heat for rapid drying, yet the basic variables associated with such heating have not been adequately investigated. One of the big difficulties in using dielectric heating, aside from its cost, has been the vaporization of liquid water to water vapor more rapidly than such vapor can diffuse through the wood. Excessive pressure is likely to be built up within the wood. A major accomplishment in the way of increasing wood permeability might reopen many possibilities in the use of such dielectric heating.

The sixth recommendation of the conference calls for research on chemical methods of controlling the seasoning process in wood. The application of a chemical, usually sodium chloride, to the surfaces of thick stock to lower the vapor pressure in the surface zone of the wood at a given temperature and moisture content, thus reducing surface checking, is fairly common. Sodium chloride serves this intended purpose quite well, but has secondary effects that may be serious under some conditions. Other chemicals that have been tried have not been so successful, for various reasons. However, there may be chemicals—polyethylene glycol, for example—that would accomplish the same end as far as controlling seasoning defects is concerned, yet avoid the harmful secondary effects of sodium chloride. Also suggested was further investigation of the variables associated with other chemical methods of seasoning wood, such as solvent seasoning and vapor drying.

The seventh, and last, recommendation of the conference calls for investigation of the application of "uncon-

ventional" forms of energy to the drying of wood. "Unconventional" was understood to mean forms of energy, or application of such forms, not currently being used in wood drying. Solar energy has been used in the air drying of lumber for years, but its storage and harnessing for use in lumber drying has not been investigated. Other energy forms, such as different types of radiant energy, should be investigated for possible applications in wood drying. This last recommended field of investigation was left wide open for the really imaginative wood researcher who might feel constrained by the somewhat more prosaic preceding recommendations.

Value of the Conference

The Conference was broader in scope than many realized at the time.

The conference recommendations cover areas of investigation that are difficult for many people to conceive as being related to seasoning, such as X-ray fringe patterns. Other areas of investigation are merely extensions of past work or work currently in progress. In this connection, it is well to keep in mind that advances in other fields are very likely to make possible advances in the field of wood drying that were not possible a few years ago. Therefore, it is important that we keep abreast of such advances. The drying conference was worthwhile if for no other reason than the fact that it offered an opportunity to share current thinking on fundamental approaches to drying problems and to be informed of recent developments in allied fields.

These recommendations for fundamental research in wood drying should not be interpreted as providing an alternative to research and development in such fields as dry-kiln operation and engineering. Rather, the results of fundamental research in laying the groundwork for improved wood drying procedures would be expected to create new, more exacting, demands in the design and operation of wood drying equipment. No drying process improvement can be of any real benefit without equipment in which the desired drying conditions can be produced and controlled. Advances in equipment engineering must therefore accompany advances in the knowledge of drying fundamentals if any real gain is to be made in commercial wood drying.

FACTORS ASSOCIATED WITH THE DEVELOPMENT OF

Collapse in Aspen During Kiln Drying[1,2]

A. E. KEMP
Head, Department of Forestry, Stephen F. Austin State College, Nacogdoches, Texas

An instrument was designed that measured and recorded small changes in board profile. Statistics showed the effect of temperature and humidity on time-to-collapse to be significant. Collapse appeared first in wetwood springwood in early drying stages while wood was well above FSP.

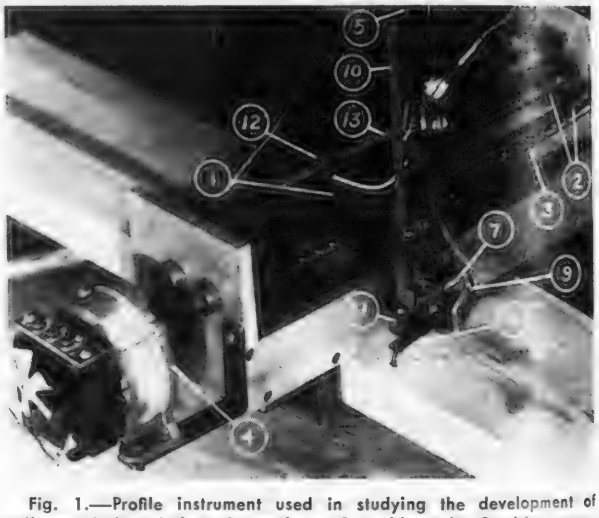


Fig. 1.—Profile instrument used in studying the development of collapse during drying. 1. carriage; 2. guide rods; 3. drive screw; 4. reversing motor; 5. vertical rod with attached measuring components; 6. lever arm; 7. wire-wound potentiometer; 8. stylus; 9. wiper; 10. verical rod; 11. electro-magnet; 12. wiper; 13. potentiometric sensing unit.

[1] Presented at Session XI, Wood Drying (Fundamental) FPRS 12th National Meeting, held June 22-27, 1958, in Madison, Wis.

[2] Part of a thesis in partial fulfillment of requirements for the PhD at the University of Minnesota. Published as Scientific Journal Series Paper No. 3953 of the Minnesota Agriculture Experiment Station.

The Author: Arne Kemp holds a BS from the University of Georgia, MF from Duke University, and PhD from the University of Minnesota. Prior to joining Austin State, Kemp was on the faculty of U. of Minnesota and Louisiana State U.

IN THE CONVERSION OF LOGS into usable products, the drying of lumber is one of the essential intermediate processes. One of the more important defects, and probably the least understood, that frequently develops during seasoning of some species, particularly during kiln drying, is collapse. Collapse, as the name implies, is the rupture of some of the wood cells and appears as excessive shrinkage as shown in Fig. 2.

While most drying defects are associated with differential shrinkage and are confined to moisture content levels below the fiber saturation point, collapse is unique in that it develops in the early stages of drying while lumber is wet and well above the fiber saturation point. The presence of the defect generally results in abnormal waste or degrade of lumber, the extent of loss depending upon the value of a given species or its ultimate utilization.

During recent years, considerable attention has been directed to the gross study of collapse as it occurs during

Fig. 2.—Location of wetwood areas in aspen boards. In board B–2, it was impossible to remove the collapse defect by surfacing.

Fig. 3.—Relative position of the board in the dry kiln as it was dried.

kiln drying, with most of the conclusions being based on the evaluation of collapsed boards taken from a kiln charge at the end of a schedule. Such work has been most helpful in developing preventive measures. On the other hand, studies of the influence of basic factors such as moisture content, temperature, humidity, and specific gravity, to mention a few, on the development of the defect have been largely neglected. Vague and contradictory explanations regarding collapse have been produced by a few researchers who have attempted to explain a complex phenomenon that embraces many interrelated factors. Furthermore, there is a dearth of information regarding the development of the defect in individual boards and the exact conditions under which it develops.

Of the many species that are susceptible to collapse during some phase of kiln drying, aspen (*Populus tremuloides* Michx.) in the Lake States has received relatively little study. During recent years the species has attained a position of considerable economic importance. Not only has the sawtimber consumption of aspen steadily increased until in 1952 it constituted the fourth highest volume cut on commercial forest land in the Lake States, but it also has the greatest net annual growth of growing stock and covers the largest acreage of any species (8).[3] If the utilization of this abundant resource for lumber is to be greatly expanded, a more precise knowledge of the properties of the raw material is necessary.

This paper is a report on a study based on the incidence, extent, and characteristics of collapse in individual aspen boards when subjected to a predetermined set of drying conditions. An attempt is made to ascertain the conditions under which collapse occurs in kiln drying, and to correlate other pertinent factors associated with the defect.

Previous Work

During the initial stages of drying green lumber of most species, a substantial quantity of free water is present. The removal of this free water is critical in the development of collapse. In 1915, Tiemann (22) observed that, when free water was removed from certain species, collapse developed. Subsequently, he offered the first explanation for the phenomenon. Since collapse occurs above the fiber saturation point, the works of Rees and Buckman (18), Brown and others (5), and Stamm (20) have been helpful in explaining the manner in which free water moves during drying. Hawley (15), Greenhill (13), Stamm and Loughborough (21), and Banks and Barkas (3) have offered other explanations that may partially account for the development of collapse in many woods.

The results from observations of many researchers indicate collapse to be associated with areas of high moisture content. Aikens and Pillow (1) have reported that tension wood fibers with high moisture contents are associated with collapse. Imperviousness of wood (7), high drying temperature (11, 13, 17, 23) and anatomical differences between springwood and summerwood within an annual increment (4) have been suggested as other factors that contribute to the development of collapse.

From the above review, it is evident that the knowledge of the phenomenon of collapse is very limited.

Experimental

Material and Test Specimen: Aspen (*Populus tremuloides* Michx.) was selected for study because of local availability, and because certain areas (wetwood) are known to collapse in kiln drying. Freshly cut and sawed aspen lumber 4 by 8 inches by 8 or 12 feet in length that showed visible zones of sapwood, wetwood and heartwood was selected from a local lumber yard. By limiting the quantity of lumber selected to that sufficient for 4 or 5 days of experimentation, there was reason-

WHAT THIS RESEARCH MEANS

Kiln drying schedules for green lumber have been evolved from trial and error procedure and more recently from a study of stress development in the lumber during the drying process. The resultant set of drying conditions adopted for a schedule will produce, in most instances, a satisfactory quality of lumber. However, in drying some species which are susceptible to the development of collapse the basic schdules are modified, frequently in such a way that the most economical drying conditions are not always attained.

Another approach to schedule modification for collapse-susceptible species is to determine the conditions under which the defect occurs. From such data the combination of drying variables which will most adequately satisfy a specific need and at the same time reduce collapse to a minimum can be selected and incorporated into the redesign of a kiln schedule. This paper contributes basic information which might be used in the modification of existing aspen schedules or for development of new ones. Similar information about other species should be valuable in modifying other schedules.

Editor

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

able assurance that fresh material was being used at all times.

After the 4-inch-thick lumber was resawed to yield pieces of approximately 2 inches in thickness, the lumber was dead piled, wrapped with impervious nursery paper to retard evaporation, and stored outdoors in a shady place. Since most experimentation was conducted during the winter and spring months when temperatures were generally below freezing, the possibility of blue stain or other fungal attack was negligible. On the day prior to use, a one-day supply of test material was removed from the pile, taken indoors, wrapped with impervious paper, and permitted to reach an equilibrium temperature of 70° F. The test material was then cut into sections of approximately four feet in length, which were appropriately marked with a letter designating the original board before resawing and the test sample number. Moisture content and specific gravity samples of sapwood, wetwood, heartwood, and cross sections were cut from the middle of each board as it was being resawed. Each test sample was surfaced four sides.

Test Conditions and Equipment: Specimens for the experiment were tested in five replications at four levels of temperature and humidity, as follows:

Temperature 140°, 150°, 160°, 170° F.
Relative humidity 40, 50, 60, 70 per cent.

Thus, 80 specimens were tested during the entire experiment. The experiment was designed as a block to permit statistical analysis of the data.

To eliminate interruption of the drying process, an instrument was designed and constructed that would permit periodic scanning of the board surface, sense small changes, and transmit these changes in board profile to recording instruments stationed outside the drying chamber. The apparatus consisted of two main parts: the profile tracing instrument, which is attached to the board (Fig. 1), and two potentiometers, one of which was a type No. 8662 Leeds Northrup and the other a Model 1117 of the Brown Instrument Co. Each instrument was connected to the potentiometric sensing circuit on the profile instrument through a selector switch and No. 22 insulated copper wire. Prior to use, the apparatus was calibrated with the range of millivolts being used to indicate dimension for wood.

The drying chamber used in this study was a laboratory unit dry kiln manufactured by the Standard Dry Kiln Co., and was provided with automatic controls and recording equipment. The drying capacity and air velocity were 500 board feet and 550 feet per minute, respectively.

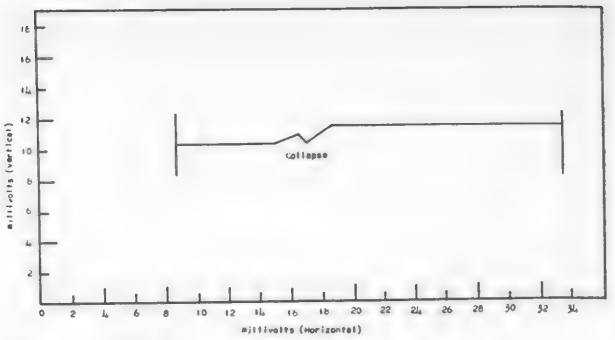


Fig. 4.—Enlarged profile of a board showing the development of collapse. Millivolts are used to indicate dimension for wood.

Test Procedure: The sequence in which the tests were made is as follows: Immediately before testing, a specimen was surfaced four sides to 1.5 by 6.0 inches and trimmed to a four-foot length by cutting the excess from the end away from the middle of the original sample. A reference line was drawn across the wide face of the board so that it would intersect the marked wetwood zones. Holes for accommodating the thermocouples were drilled to a depth of three inches into the narrow edge near the reference line.

After the test sample was placed in a pre-heated dry kiln, the instrument was fastened to the board so the stylus would traverse the reference line. The thermocouples were inserted into the predrilled holes and attached to the surface, and the board was then placed into position for drying (Fig. 3). For reference purposes, initial millivolt readings were taken for the test-sample edges, for wetwood zones, and for board profile. Subsequently, the drying conditions were set on the automatic kiln control and the kiln was started.

During the drying period, profile and thermocouple readings were taken at intervals of 20 minutes or less. Since the wetwood zones are most susceptible to collapse, particular attention was given to the profile readings within those zones. Collapse was detected by (a) observing the movement of the galvanometer needle in response to changes in board profile as measured by the stylus and (b) comparing the successive millivolt readings with the initial information. To verify the initial detection of time-to-collapse, an additional profile reading was taken after 10 minutes had elapsed. Sample millivolt readings are plotted and shown in Fig. 4.

After collapse had developed, the board was removed from the dry kiln and weighed. Any visible evidence of external defects that had developed during drying was recorded. Shell, core, and cross-section moisture content samples were immediately cut from the collapsed areas of the test sample. Sections for determining moisture content and specific gravity were also cut from the sapwood, wetwood, and heartwood.

Results

Fig. 5 is an example that shows the relationship between drying time and board temperature for a series of drying conditions.

To determine the type of curve and equation that would express these data most accurately, a method of orthogonal polynomials as suggested by DeLury (9) was used. This method is well adapted to the equal-spacing sampling of this experiment. After the type of curve was determined, the regression equation was computed and the estimated value of time was derived.

Figs. 6, 7, and 8 show the effect of humidity and temperature when the original data for each condition has been plotted and the curve based on the estimated value of time-to-collapse has been fitted. Thus, it is possible to judge trends, closeness of fit, and the extent to which the data might be extrapolated. The combined effect of temperature and humidity is shown in a three-dimensional graph (Fig. 9). So that the trend of humidity might be more clearly defined, the range of humidity was extrapolated to include an interval of 10 per cent on each end. It is realized, of course, that any conclusions based on such extrapolation might be questionable.

Discussion

In his study of collapse, Greenhill (13) has stated that collapse develops in areas of green wood that are completely saturated with moisture. The movement of free water in the drying process is possible only when the tension caused by the evaporation is sufficient to cause the cell fibers to collapse,

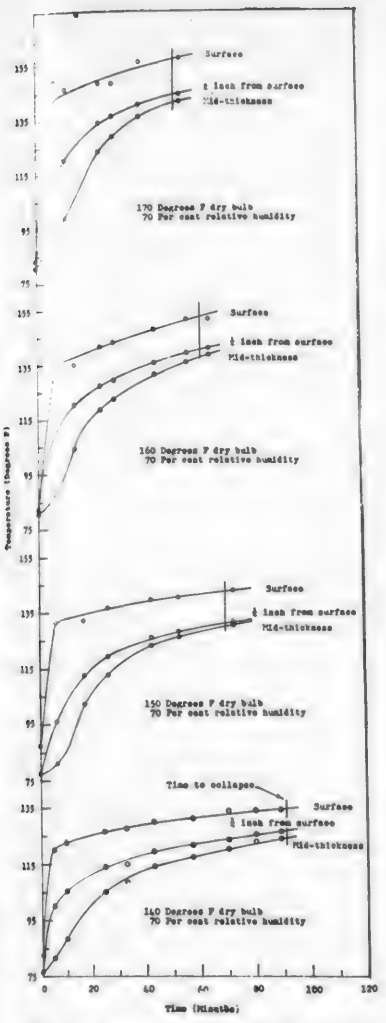


Fig. 5.—Relationship between drying time and board temperature when the board was dried under varying temperature and constant relative humidity.

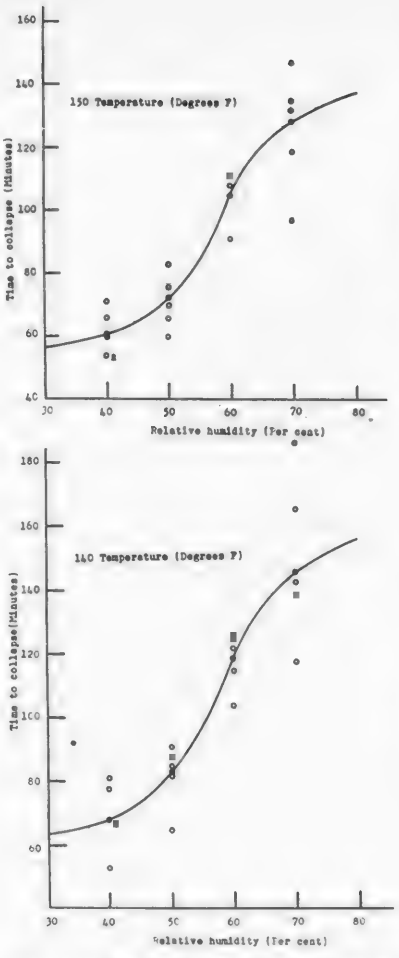


Fig. 6.—Effect of humidity on time-to-collapse at 140° and 150° F.

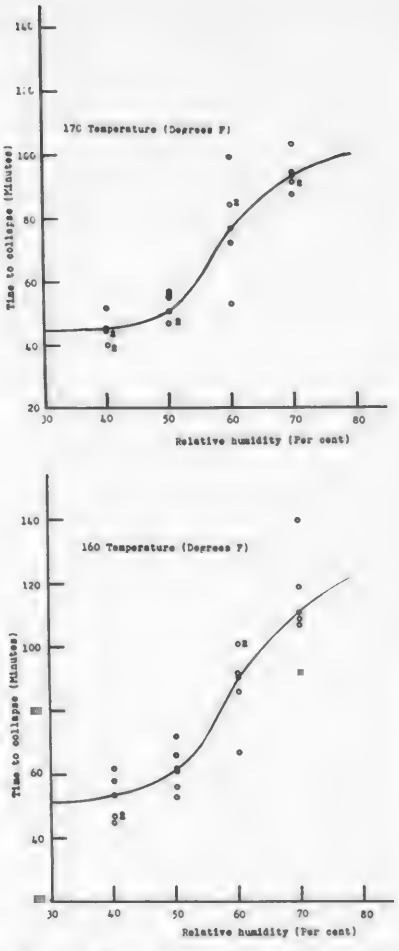


Fig. 7.—Effect of humidity on time-to-collapse at 160° and 170° F.

thus relieving the restraint. In the case of green softwoods, the elastic limit for compressive strength perpendicular to the grain is about 500 psi. According to Stamm (20), this corresponds to a vapor-pressure reduction of 0.025 and a capillary radius of about 42 millimicrons. All fibers are not expected to meet the requirements. Only those completely saturated fibers with an effective capillary radius of 42 millimicrons are considered. Since the compressive strength perpendicular to the grain of aspen lumber is approximately 500 psi, it can be assumed that collapse conditions suggested by Stamm for softwoods may be applicable to aspen.

In the present study, collapse in aspen was invariably found to develop first in the wetwood zone, which in this case varied in width from approximately one-fourth to one-half inch. Moisture content determinations from wetwood indicate that at no time did the initial moisture content approach complete saturation. Furthermore, *t* tests revealed that the moisture content of sapwood, wetwood, and heartwood differed from each other at the one per cent level. If the postulations presented by Stamm and Greenhill are considered valid, the development of collapse as observed in the present study would have been impossible.

The combined effect of temperature and humidity on the time-to-collapse was found to be highly significant. Furthermore, the effect of each condition of temperature or humidity on the time-to-collapse was also found to be significant. Since the temperature and humidity value of 170° F. and 70 per cent showed the greatest significance, it can be concluded that the two conditions probably had the greatest effect on the time-to-collapse.

That collapse develops during the early part of a drying schedule is shown by observing the time-to-collapse of the various series of test samples. When the aspen samples were dried by the severest condition of 170° F. and 40 per cent relative humidity, the average time during which collapse started developing was 44.4 minutes, whereas collapse developed in 149.6 minutes when the mildest schedule of 140° F. and 70 per cent relative humidity was used.

Examination of the statistical analysis and the data in Figs. 6, 7, and 8 indicate that the effect of temperature on the time-to-collapse may be best expressed by a first-degree linear, and the effect of humidity by a third-degree curvilinear relationship. At any constant relative humidity, as the temperature increased the time-to-collapse decreased. On the other hand, if the relative humidity is increased at a constant temperature, the time-to-collapse increases at a changing rate defined by a sigmoid curve.

In the lower region of Fig. 9 (between 30 and 40 per cent humidity), the time curve becomes almost horizontal. The effect of relative humidity is essentially at a minimum with a corresponding minimum time. This might suggest that collapse does not develop instantaneously upon being subjected to a given set of drying conditions, and that a minimum time is required for heat transfer to cause evaporation. In the upper region of

the sigmoid curve between 60 to 80 per cent relative humidity, the curve shows a tendency to level off, which suggests that above 60 per cent the effect of humidity on time-to-collapse decreases with an increase in relative humidity and intersects the time axis at a finite value under conditions of 100 per cent relative humidity. Thus, it is conceivable that collapse could occur near 100 per cent and would tend to support the work of Greenhill (13), who illustrated mathematically that collapse could develop in a cell with an opening of 70 mu diameter under a relative humidity of approximately 97 per cent.

Since moisture content determinations of the wetwood zone in this experiment have shown that the area is incompletely saturated, the explanation for the sigmoid curve in Fig. 9 can be based on the drying behavior of green wood, which has some air in the cells in addition to free water. Movement of moisture to the surface then is possible as free water, absorbed water, vapor, or by a combination of any or all of the three mechanisms.

If one assumes an interdependent action among the mechanisms of moisture removal above fiber saturation point, the changing rates of time-to-collapse would indicate that the degree of interdependency among the mechanisms tends to vary with the surrounding conditions; that is, free water may be greater at one increment of humidity versus another. The extent that water movement by the different mechanisms might vary is not as yet predictable.

There are two concepts that might help to explain the flat slope of the time-to-collapse surface between the relative humidities of 30 and 40 per cent. The first concept is based on the moisture content of the wood at the surface and its possible effect on the development of collapse. Although moisture content determinations of the shell from the wet line to the surface revealed the shell to be well above the fiber saturation point at the time of collapse, it is very possible that a thin layer of surface cells could have dried below the fiber saturation point. Since the rate of diffusion at fiber saturation point is in the order of six times that for dry wood, a thin, dry surface layer of wood could materially alter the rate of moisture loss from the surface of the board. Rapid surface evaporation could have dried the fibers below the saturation point before collapse had time to develop, and thus retarded subsequent evaporation and slowed down the rate of time-to-collapse. As the relative humidity is increased, a correspondingly higher moisture content would be evidenced by the thin layer of wood, thereby accelerating the total rate of moisture movement. This is consistent with the findings of Martley (16) that "The relative humidity of the circulating air should be so high as to keep the moisture content at the surface of the wood high in order to take advantage of the greater diffusivity of moisture at the higher moisture contents."

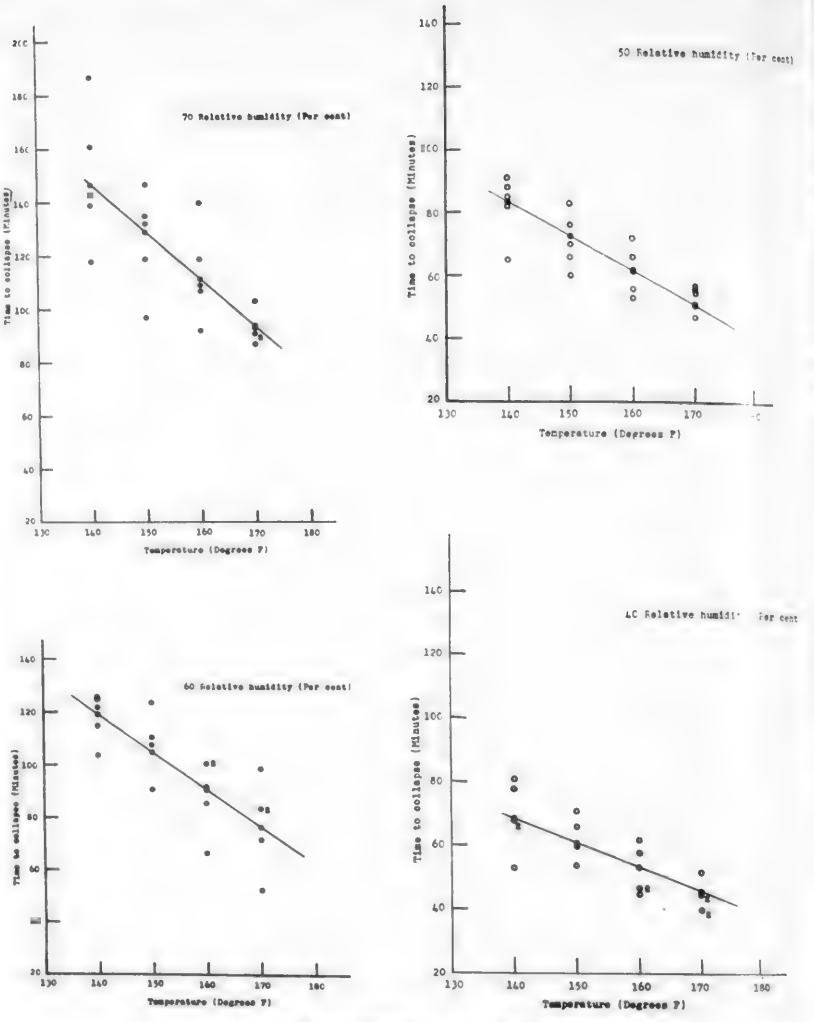

70 Relative humidity (Per cent)
50 Relative humidity (Per cent)
60 Relative humidity (Per cent)
40 Relative humidity (Per cent)
Time to collapse (Minutes)
Temperature (Degrees F)

Fig. 8.—Effect of temperature on time-to-collapse.

In the second concept, consider a cell *A* full of water with a membrane capable of producing a tension *Ta* during evaporation. If the surrounding cells are also saturated and have a membrane larger than in cell *A*, under a slow rate of drying there is a possibility that water can gradually diffuse from the adjacent cells into cell *A* due to a slight tension difference. The diffusion of moisture into cell *A* would tend to reduce the tension stress within the cell below the maximum the membrane is capable of producing, thereby tending to minimize the rate and extent of collapse development.

On the other hand, if the rate of drying is rapid, such as at relative humidities of 30 and 40 per cent, there is a likelihood that water cannot diffuse rapidly enough from the adjacent cells into cell *A* to reduce the tension, *Ta*. Consequently, a much greater tension stress will be induced than at the slower rate of drying. The magnitude of the stress will depend on the rate that water can diffuse from the contiguous cells into cell *A*. Hence, the more rapid the rate of drying, the greater would be the force tending to collapse the cell. It is also reasonable to expect that the increased force would reduce the time during which collapse developed.

Applying this concept to the 30 and 40 per cent relative humidity conditions in this experiment, it is possible that the diffusion of water from the contiguous cells into the cells subjected to a collapse-producing tension stress may have reached a maximum rate at approximately 40 per cent, and any further reduction in relative humidity would have little effect on increasing the rate of water diffusion from cell to cell. This, then, could cause a leveling effect on the time-to-collapse as

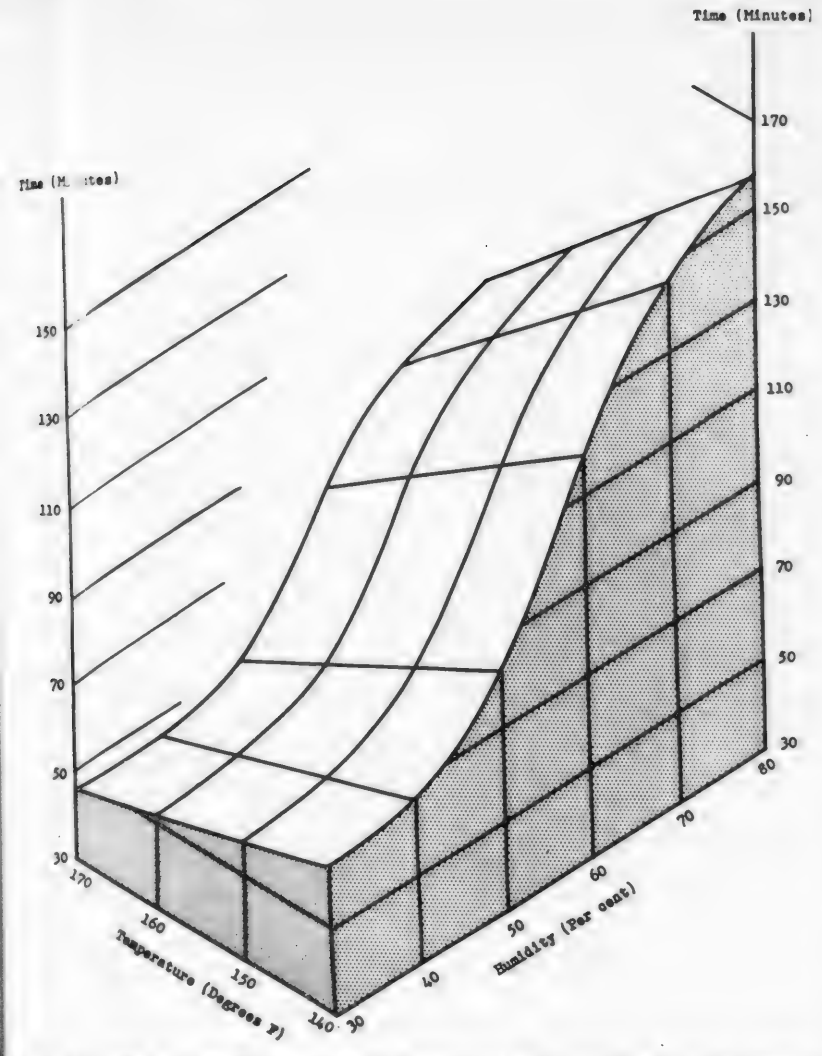


Fig. 9.—Effect of varying combinations of temperature and humidity on time-to-collapse.

Fig. 10.—Development of collapse in the springwood of aspen wetwood.

shown in Fig. 9. Tiemann (24) has stated that "The water tension force within any cell cannot exceed the resistance to its removal, even though the extraction occurs through an impervious membrane whose openings are small enough to set up a much greater force." It is conceivable that, at 40 per cent relative humidity, the resistance to water removal began to approach the maximum.

In analyzing Fig. 9, it should be noted that the slope of the time-to-collapse plane for relative humidity is appreciably greater than that of temperature when increments of 40 and 60 per cent relative humidity are considered. This tends to indicate that, within that region, relative humidity might be a more important factor than temperature in regulating the development of collapse. At the upper limits of temperature and humidity, the effect of relative humidity on the time-to-collapse shows a decreasing trend. This was as might be expected if, at higher temperatures and humidities, plasticization of wood becomes increasingly important. Thus the individual effect of temperature or relative humidity might be different from that found in the lower region of the curve.

In the present study it was noted that collapse developed in the first half of the annual ring, or presumably what might be considered as the springwood zone (Fig. 10). The occurrence of collapse in the springwood zone could be readily attributed to a lower specific gravity in that region. If the test boards were permitted to air dry for a period of 12 hours after being removed from the dry kiln, collapse extended over an area covering several growth rings.

That the strength properties of springwood of aspen wetwood might be lower than in corresponding summerwood was further demonstrated by the position in which shake occasionally developed in some boards when they were permitted to dry below the fiber saturation point. In each case, shake developed in the springwood area of an annual ring. Of particular interest was the fact that the shake invariably developed only in the wetwood zone. This might be partially explained by the presence of a greater stress in that area. On the other hand, confinement of shake in the wetwood zone may also suggest a weakening effect in that area due to some organism, possibly bacteria.

The development of collapse and shake in the wetwood zone cannot be logically attributed to specific gravity differences between sapwood, wetwood and heartwood. A t test revealed that there was no significant difference between sapwood and wetwood specific gravities. On the other hand, the difference between wetwood and heartwood was found to be significant at the one per cent level.

In examining the collapsed area in the wetwood zone, it was found that collapse was frequently associated with a yellow discoloration. Microtone sections of the discolored area showed that the vessels contained a yellowish substance, which is assumed to be an infiltration product. The accumulation of the infiltration product in the vessels can arise in a manner as suggested by Chattaway (6), who suggested the parenchyma cells undergo an abnormal increase in the rate of metabolism before they pass into the heartwood stage. Such an increased rate of metabolism may cause the release of infiltration products into the surrounding tissue. Although the individual effect of the yellowish substance on the rate of collapse is not readily determined, it is conceivable that some of the passages through which moisture moves may have become partially or wholly occluded in the infiltration process.

An intensive study of the wood anatomy of collapsed zones, such as pit membranes and other passageways through which moisture moves, by electron microscopy may help to supply some of the answers as to whether the size of the passageways has undergone change from those of the original wood or if the passageways are of the approximate theoretically calculated size.

In the development of a kiln-drying schedule, a trial-and-error procedure is generally pursued. Frequently, aspen is susceptible to the development of collapse. The availability of basic information such as that furnished by this study should enable a researcher to make a more intelligent approach to the selection of drying conditions that will produce the most desirable results.

Summary

An experimental technique was described for studying the behavior of collapse under varying drying conditions. Within the temperature range of 140° F. to 170° F. and relative humidity range of 40 per cent to 70 per cent, the following was established:

1. The trend of time-to-collapse to temperature was expressed by a linear relationship and to relative humidity by a third-degree relationship.

2. Collapse in aspen developed during the early part of a drying schedule; the time-to-collapse varied from 44.4 minutes to 149.6 minutes after drying commenced.

3. Since the moisture content determinations show that the zone most likely to collapse—wetwood—was incompletely saturated, the sigmoid relationship between time-to-collapse and relative humidity was explained on the behavior of green wood. The flat slope between the relative humidity conditions of 30 and 40 per cent was attributed to: (a) a thin surface layer of wood below fiber saturation, which would reduce the rate of evaporation approximately to a constant rate, or (b) the rapid drying rate, which would cause a tension force to build up within a cell subject to collapse at a faster rate than water diffusion from adjacent cells could minimize the stress. The resistance to water removal was believed to have reached a maximum at approximately 40 per cent, after which it tended to maintain a constant magnitude.

4. Statistical analysis of the relative effect of the variables, humidity and temperature, on the time-to-collapse showed that at certain levels the relative humidity may be a more significant factor than temperature.

5. Observations of the development of collapse within the annual ring revealed that the defect initially started in the first half of the ring, or what might be considered mostly as the springwood zone. It was also noticed that shake occasionally developed in the same zone, notably in wetwood.

6. Additional evidence of an abnormally high moisture content in the wetwood area of aspen was presented. Collapse was found to develop while the entire test specimen was above the fiber saturation point. Frequently, collapse was found to be associated with a yellowish infiltration product.

Additional work on the development of collapse in other species and the significance of the air-water ratio within the cells susceptible to collapse is planned.

Literature Cited

1. Akins, Virginia and M. Y. Pillow, 1950. Occurrence of gelatinous fibers and their effect upon properties of hardwood species. FPRS Proc. 4: 254–264.
2. Anon. 1934. Collapse and the reconditioning of collapsed timber. Trade Circular No. 20. Council for Scientific and Industrial Research, Division of Forest Products, Australia.
3. Banks, W. H., and Barkas. 1946. Collapse of capillaries in the drying of porous gels. Nature 158:341.
4. Bissett, I. J. W.,and E. L. Ellwood. 1950. The relationship of differential collapse and shrinkage to wood anatomy in Eucalyptus Regnans F. uM and Eucalyptus Gigantea, Hood. CSIRO, Australia.
5. Brown, Panshin, and Forsaith. 1952. Textbook of wood technology, Vol. 11. McGraw–Hill Co.
6. Chattaway, Margaret. 1952. Sapwood-heartwood transition. CSIRO, Australia 16:1, pp. 25.
7. Clausen, V. H., L. W. Rees, F. H. Kaufert, 1949. FPRS Proc. 3:460–468.
8. Cunningham, R. N. 1956. Lake states timber resources. Lake States Forest Expt. Sta. Paper No. 37, USDA, Forest Service.
9. DeLury, D. B. 1950. Values and integrals of the orthogonal polynomials up to $n = 26$. Univ. of Toronto Press.
10. Elliott, C. S. 1930. Australian Council for Scientific and Industrial Research Circular 3.
11. Ellwood, E. L. 1952. The seasoning of rotary peeled veneer from Eucalptus Regnans F. V. M. J. of Applied Science, Australia 3 (1):54–70.
12. Espenas, L. 1953. Seasoning of one-inch tanoak lumber. Oregon Forest Prod. Lab. Bul. 3.
13. Greenhill, W. L. 1938. Collapse and its removal: Some recent investigations with Eucalyptus Regnans. Council for Scientific and Industrial Research, Div. of Forest Products, Australia. Pamphlet No. 75.
14. Guernsey, F. W. 1951. Collapse in western red cedar. Forest Prod. Research Div., Forestry Branch, Dept. of Resources and Development, Ottawa.
15. Hawley, L. F. 1931. Wood liquid relations. U.S.D.A. Tech. Bul. 248.
16. Martley, J. F. 1926. Moisture movement through wood: The steady state. (Great Britain) Department of Science and Industrial Research, Forest Prod. Research Tech. Paper 2, 22 pp.
17. MacLean, J. D. Effect of steaming on the strength of wood. A.W.P.A. Proc. 49:88–112.
18. Rees, L. W., and S. Buckman. 1938. Moisture movement in wood above fiber saturation point. J. of Agr. Research 57:3 161–188.
19. Smith, H. H. 1947. Seasoning of aspen. Lake States Aspen Report No. 5, USDA, Forest Service.
20. Stamm, A. J. 1946. Passage of liquids, vapors and dissolved materials through softwoods. United States Department of Agriculture. U.S.P.A. Tech. Bull. 929, pp. 1–80.
21. Stamm, A. J., and W. K. Loughborough. 1942. Variation in shrinking and swelling of wood. Am. Soc. of Mech. Eng.
22. Tiemann, H. D. 1915. Principles of kiln drying. Lumber Wood Review.
23. Tiemann, H. D. 1938. Lessons in kiln drying. Distributed by Southern Lumberman.
24. Tiemann, H. D. 1944. Wood technology, 3rd Edition, Pitman Publishing Corp., New York.

Discussion

A. J. Stamm (U. S. Forest Products Lab): Can you give an estimate of the number of fibers in the thickness direction that collapsed during the heating period?

Dr. Kemp: The vertical calibration was 1.0 millivolt equals 0.006 inch. Collapse generally was detected when successive readings varied by approximately 0.5 millivolt. Since the readings were taken at intervals of 20 minutes, the millivolt variation could have been less than 0.5 millivolt. Assuming 0.5 millivolt as average, the corresponding thickness of fibers would have been equivalent to 76 microns, or about two or three thicknesses of fibers

C. Skaar (New York State College of Forestry): Did you make any measurements of the compressive strength of the aspen wood used in your studies and attempt to correlate the effect of temperature on compressive strength across the fibers with your results on the effect of temperature?

Dr. Kemp: No, the study would have become too involved.

Dr. Skaar: Did you attempt to observe the cells that collapsed under the microscope?

Dr. Kemp: No. However, observations of wetwood, which is susceptible to collapse, before drying revealed that frequently a yellowish substance was found in the cells.

A. C. Barefoot (N. C. State College): Did you suspect or surmise that the zones of collapse in your samples were located in bands or areas of tension wood? If so, would the change in structure associated with these fibers influence the tendency for collapse to occur?

Dr. Kemp: Although tension wood has been suggested by some researchers as contributing to collapse, in this study it was not surmised that the zones of collapse were located in tension wood areas. Since wetwood is the area that generally collapses, and since there is no conclusive evidence to show that wetwood is always tension wood, it would have been erroneous to assume that collapse was located in areas of tension wood. Although tension wood fibers might tend to influence the development of collapse, they would probably have the same effect throughout the entire range of test conditions.

DESIGN POSSIBILITIES OF

Automatic Shapers and Routers-

E. PANKONIN
Vice President and Director of Engineering, Niles, Illinois

Function and economy factors must be combined in practical machine design. The redesign of a router is described. Future shapers may have: two motor heads, tracer-control systems.

THE ROUTER IS A VERTICAL-SPINDLE, high-speed type of machine that usually has a revolving high-speed small cutter to machine grooving types of cuts. This type of machine goes back some 35 years, at which time direct-drive, high-speed air turbines were used. During successive years, the electric drive came into being and the spindle was rotated either by a direct high-frequency electric drive, or by a belt drive from a standard 3600 rpm motor. The basic functions and operations of a router are the same as they were 35 years ago. The operator uses a form that rides against a guide pin, a fence, or other specific type of follower device.

Routers

Usually, the styling of a machine (Fig. 1) follows a pattern. The mechanical design is placed on paper first, and then the stylists are brought in to work on the outward appearance. In this case, seven different outward "new looks" were presented for consideration. Needless to say, many modifications were required mechanically to fit the two together.

The appearance of the router was formulated into the present design to cut the cost of manufacture as well as for the new design look itself. This was one of the fundamental purposes, and coupling it together with functional improvements became the goal.

The major item on a medium-size machine such as this is the stand.

[1] Presented at Session II, Wood Machining, FPRS 12th National Meeting, June 22-27, 1958, Madison, Wis.

Seven different appearance designs were evaluated in the redesign of this router.

Many mechanical modifications were required before reduced manufacturing costs could be correlated with improved appearance and functional operation.

Shaping "T"-squares on a six-station holding fixture and pattern. Future shapers may have two motor heads.

Structurally, the new design is similar to the previous model, but weightwise it is heavier. Yet by virtue of simplification of cores plus a different casting process, the casting can be purchased at a lower price. Greater advantages and savings are achieved by having a casting that is more accurate dimensionally. A truer and smoother casting permits the elimination of machining on many surfaces to the extent that the machine time on this particular part is cut by approximately 40 per cent.

The knee has been designed slightly smaller than previously, but in such a way as to permit Blanchard grinding instead of milling on the ways for additional cost savings.

A considerable portion of time is spent in assembly. This redesign accomplished a substantial saving in this area. The spindle assembly is now bolted to the stand with a flange-type mounting instead of a face-type fit. The top and back of the stand are open and accessible making it easier to mount the pulley assembly, the motor and belt-drive assembly, and the electrical equipment. After these components are assembled into the stand, cover plates are bolted to tie in the whole structure very rigidly.

Another cost saving, which is also a very desirable feature, was achieved by changing the motor drive pulley from aluminum to a non-metallic material and redesigning an external lever braking system to a pushbottom electric brake. Although the saving is not substantial, it is on the whole very worthwhile because of the beneficial improvement in function and sales points directed to the operation and maintenance of the machine.

Many of the savings previously mentioned tie in very definitely with features. The remaining feature derived from the redesign was the operation that allows control of the cutter vertically in and out of the wood. The new design is based on a remote-control method of operation whereby the foot pedal can be placed around the machine in any desired location rather than be attached solidly to the machine proper. The operator can place the foot control in the most convenient place for large or small work.

The vertical control of the spindle is operable to any desired position by depressing either side of the pedal on the foot valve. When the pedal is brought to a horizontal position, both ends of a cylinder are locked, which in turn holds the spindle at the required height. The cylinder is controlled pneumatically and can be operated very rapidly to the multiple depth stop provided on the machine.

Shapers

Automatic shaping allows a piece to be put on a moving table, which is usually rotating, and automatically contoured by means of a pattern placed directly below the work. A roller concentric with the cutter follows the path along the desired shaped on any wood part.

The evolution of automatic shaping goes back many years, and started with the shaping of round pieces completely around the periphery, thence to square and rectangular pieces shaped on two, three, or four sides.

The next step was to have station clamps so pieces could be shaped on one side, turned around, and shaped on the other side.

In recent years, the automatic-shaper type of operation has achieved inside shaping. The spindle and cutter are positioned over the center of the piece, then automatically brought down, and simultaneously moved outward in the horizontal plane to a stop to shape the inside contour of pieces. Items such as toilet seats and picture frames are examples of this type of operation.

In some instances it is necessary to load and eject piece parts automatically to facilitate production and handling. Hopper feeds have been added to machinery, but feasibility of this adaptation is dependent on the select group of piece handled, and the amount of production. In many instances it is very practical to have one operator control two or three machines. The gain in productivity is achieved by making these shapers semiautomatic so that the operator loads and unloads one machine and starts the cycle while he goes on and does the same on a second and sometimes a third machine.

Versatility of the Shaper

Another very productive type of automatic shaper for special application contains cutter heads in the horizontal plane to do vertical profiling while being turned on an arc from the center of the table. Chair backs, shuttles, and coat hangers are examples of this type of work, with production figures on some parts running as high as 30 per minute.

The automatic shaper lends itself to other types of operation besides shaping. In station work it is possible to do auxiliary operations such as boring of holes, which ordinarily require additional capital outlay for machinery and floor space. These can be combined into one operation on the automatic shaper. This is possible while the table is revolving or can be accomplished with indexing stations so that the drilling and boring can be done from a non-revolving or stationary table.

Another type of automatic shaper would have two motor heads on it. It would be very much similar to the present concept of automatic shaping, but along with it and projecting from the same pivot shaft would be an inverted motor that comes up from the bottom. The possibility of using both heads simultaneously lends itself very well to this particular type of operation, and will step up production almost 100 per cent by virtue of shaping two sides instead of one simultaneously.

An innovation yet to come and fostered by many forward-looking people is the addition of tracer control to a machine in this category. Present shaping is accomplished with a roller concentric to the cutter which maintains template or pattern contact up to 100 pounds through a pressure-loaded arm.

Conversion to tracer control would reduce this pressure considerably and allow the use of lighter templates. A stylus would be substituted in place of the roller. When the stylus is deflected by the template or pattern, a signal would be sent to the control system, which would deflect the stylus either away or back into the pattern. Tracer-control systems (whether electronic or hydraulic) work on an error signal to guide the cutter through the desired contour. This design would be termed a "mechanical feedback" system because the control medium is physically tied to the cutter head.

Some advantage would be gained through the use of a tracer-control system, but at this time major disadvantages prevent its successful use. Production rates for continuously changing contoured parts would not measure up to figures now achieved by conventional shaping methods. Likewise, the added costs to install tracer equipment would raise the cost of this type of machinery substantially so that its purchase price might be prohibitive.

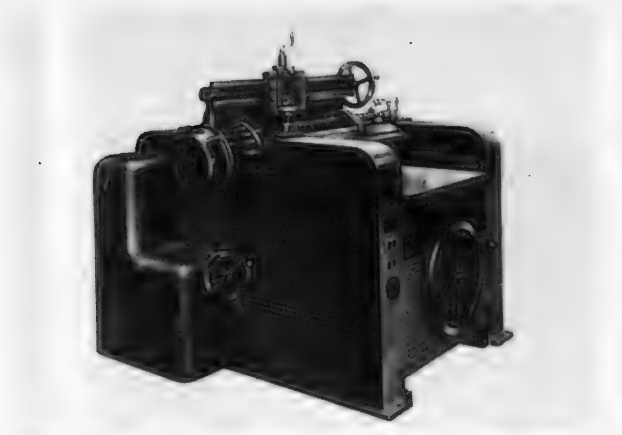
Discussion

Richard Vaughn (L. Vaughn Co.): Has any design been made on overhead routers to prevent chip interference when running against a fence and/or with patterns that are run on a pin projecting above the bottom table by means of a honeycomb table?

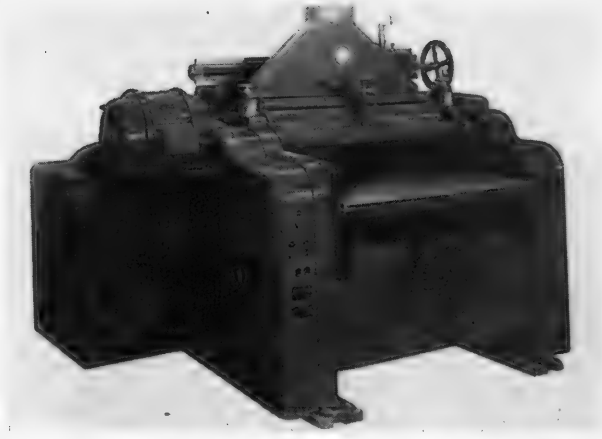
Mr. Pankonin: No one has requested such a table

Mr. Vaughn: Is it possible to use air or hydraulic pressure to move the head or table of the router up and down? Are there any manufacturers now making such a machine?

Mr. Pankonin: Yes, you can use air or hydraulic pressure. The router described is furnished either way. The spindle is moved in this manner.



Rugged, one-piece grinding rail is needed for grinding carbide knives.



Micrometer chip-breaker adjustment raises pressure fingers automatically.

WHAT TO EXPECT IN

Woodworking Planer Development[1]

J. C. Petter
Vice-President, Buss Machine Works, Holland, Mich.

Semi-automatic controls can reduce the skill necessary to operate high-speed equipment. Carbide knives will greatly reduce maintenance costs. However, improved cutting and machining techniques must precede real developments in machinery.

One of the most difficult problems facing the woodworking machinery manufacturer is the skill of the labor who will operate this high-speed equipment. In planers, semi-automatic controls have been developed with which the new or unskilled operator may set up his machine without great knowledge.

For example, in the roughing or preliminary planing operation, as the rough lumber goes into the machine it is necessary to carry the lower feed rolls higher so that the rough stock, when sliding across the platens, will not bind or twist between the pressure members. Therefore the ability to raise the lower feed rolls automatically for carry-through is a feature of great merit. The same applies to the pressure-bar control, where the pressure bar behind the top head can be raised above the cutting circle of the knives, and thereby reduce the pressure that would tend to flatten out stock that is rough on the bottom. Thus, for a dual-purpose machine, for both roughing and finishing, the operator can instantaneously raise the lower rolls or raise the pressure bar and run the stock through at a high rate without binding or twisting. Then, for the finishing operation, the lower rolls can be lowered a few thousandths above the center table, just enough to carry the stock through the machine. The pressure bar is brought back so it is even with the cutting circle and holds the piece of lumber or panel rigid during the finishing operation.

The only alternate to these automatic controls is either a compromise setting where the rolls are too high for finishing and too low for roughing, or laborious adjustment of the lower rolls and bar, by use of setting blocks, dial indicators, or other tools, which may need a relatively more skilled application.

Necessary with machine simplications and set-up are the one-shot oiling system, graduated dial controls, and quick-reading feed rate indicators.

Although these changes seem, fundamentally, like very simple things to the machinery buyer or plant superintendent with years of woodworking experience, nevertheless service engineers report that many of these features are most readily received by the planer operator himself.

Carbide Knives

In the past several years, with the development by carbide companies of processes to manufacture long jointer and planer knives, there has been a slow but definite swing to the use of these knives in planing equipment. Around 1951, it was found that, when knives were ground by the knife fabricator and were hand-set into planer cutterheads, a very fine degree of finish and excellent knife life was obtained. After the knives were resharpened in the machine, however, a definite drop in efficiency resulted. The cutting edge of the carbide, due to the grinding apparatus, was jagged, and tear-out and raised grain resulted. A research project sponsored by Buss at the University of Michigan, found that grinding apparatus used for many years on high-speed-steel knives simply would not have the necessary rigidity to grind carbide knives without chipping. As a result, the grinding wheel and jointer apparatus were redesigned so that the grinding wheel could be fed across the carbide knives so they could be ground to sharpness in an economical manner. Today there are over 150 woodworking plants in this country using carbide planer knives with satisfactory results.

An example of a carbide application reported by the Carbology Co. was obtained from the Dexter D. Hulsart Co.

[1] Presented at Session II, Wood Machining, FPRS 12th National Meeting, June 22-27, 1958, Madison, Wis.

The Author: Jay Petter graduated in mechanical engineering from the University of Michigan. In his present position, Petter is involved in sales, research engineering, and product development.

of Tuscaloosa, Alabama, which has been operating a Buss 40-inch cabinet double planer for about two years in production. This company's product is core stock, and the machine does rough and finish surfacing in ranges from 50 to 75 feet per minute. The products are panels of poplar, magnolia, white oak, mahogany, walnut, and limba.

Mr. Hulsart,president of the company, stated that in a year of operation he had ground his Carboloy knives twice and jointed them twice, with no decrease in surface qualiy over their previous high-speed-steel knives. With high-speed-steel knives, they jointed every 3.3 hours, and ground after several joints. He found that prior to the installation of carbide knives he was spending an average of 6 hours a week maintaining his knives for quality panel work. The firm produced an average of 14,000 board feet of various types of lumber per day. He calculated that with carbide knives he spent only 8 hours during a year in knife grinding, whereas with high-speed-steel around 300 hours were spent in knife maintenance.

If the maintenance is allotted within the production day, there is greater than a 10 per cent increase in production because the machine is available for more hours per year of planing and for the production of finished planed panel stock. Also, Mr. Hulsart stated that since there was practically no knife maintenance, there was also no need for planer set-up time. For all practical purposes, the double-surface planer became a single planer in set-up operation since there was practically no setting for the bottom head arrangement.

Grinding Costs

Buss calculates that maintenance of knives to the highest degree of efficiency on a planer in normal full production will result in a cost, over a period of 6 to 8 years, that is approximatey equal to half the original selling price of the planer.

For example, on a conveyor line where a 36-inch planer is installed with semi-automatic controls, one-shot oiling and other necessary items, cost is $9,000.00. To maintain maximum efficiency in rough mill, knives should be ground once a day. If it is assumed that a man's grinding and set-up time, putting away tools, and so forth would run an hour, grinding each day would be five hours a week, or 250 hours a year spent in knife maintenance. On a wage scale of $1.50 a man and 2-to-1 burden, it costs $3.00 per hour to have a man in the plant grinding equipment, which is $750.00 a year, and in 6 years $4,500, roughly half the selling price of the machine.

A set of 36-inch carbide knives sells for around $1,000. Baker Furniture Co. in Holland, Michigan has had a set of carbide knives for several years, and only grinds several times a year. From a standpoint of the labor hours needed to maintain a planer in production, it would appear that the carbide knives are an outstanding bargain, cost-wise, and result in many dollar savings over a period of years. With the techniques worked out, nicks can be repaired so that the risk factor from encountering metal is reduced. The use of carbide knives therefore does give increased production and is equivalent, in many cases, to increasing the feed rate of the planer.

Design steps to obtain this efficiency have been developed. The body diameter of planer cutterheads has been. increased. Double bearings and additional rigidity have been added through heavy motor ball bearing housings. This trend, of course, closely follows that of the machines in the metal-working trades, where it was found necessary to "beef up" and redesign the machines to give the necessary rigidity for carbide cutters to stand up under the cutting loads. In the case of jams and overloads, safety pins, heavy chipbreaker frames, and wedge devices are used to prevent knives from getting into the head.

The reluctance to use carbide knives has been considerably reduced in the past two years, and this of course is because of the many test cases available. Although the practice may now be discontinued, the only way the carbide people could first put carbide knives across to the woodworking industry was by guaranteeing that, if the knives were not satisfactory in all meanings of the word, they could be returned at no obligation. It is true that the condition of the planer and the grinding apparatus must definitely be considered before putting in the knives, and possibly these parts are reworked or new and different ones purchased. With the design trend and changes made today, the woodworking planer is most adaptable to carbide knives.

What the Future May Be

It is unfortunate that we cannot state that, as a result of research work, not only has there been an increase in the productivity of the machine, because of the carbide knives, but also that the feed rate has been increased without decreasing surface quality. This statement cannot be made, however, because we have not found that the knives produce the same quality of work at higher feed rates.

A machinery development normally suggests an increase in surface quality or productivity of the equipment, since that is the primary reason why the machinery man sells his new equipment to the woodworking industry. There is, however, a hampering or limiting factor in machine design. The inability of most cutterhead machines to give a higher production rate is normally because of the quality of work, and the quality and surface finish of the wood. Most woodworking machinery manufacturers will agree that this is the point where productivity stops.

For example, Buss has, over the years, collected articles, technical journals, and books that give data on cutting angles, cutterhead speeds, surface finish, and determination of quality and controls, not only by authorities in this country but also in Sweden, Germany, and England, as well as by manufacturers of equipment for woodworking machines. Interestingly enough, there is a wide field of disagreement. For example, in the machining of yellow poplar, the recommendations for the cutting angle among the authorities vary from zero to 30 degrees. In regard to hard maple, the authorities agree or disagree from minus 5 to plus 25 degrees. It is obvious, therefore, if the production of cutterhead machines is to be increased and quality maintained, there must be investigations on a wide-scale basis into cutting angles, knife projection, chipbreaker radii, clearance angles, joints, knife vibration properties, and cutterhead clearances to establish reliable data. Manufacturers of machinery and manufacturers of wood components must have these data if productivity is to be increased.

There has been some fine work done in this field, but the problem is greatly involved because of the variables in wood and wood processing techniques. Some day there will be established data with the variables in the rotating cutterhead machines more neatly pegged so that both manufacturers and producers will enjoy the mutual benefit of increased productivity.

Real developments in woodworking machinery must be accomplished by developments first in cutting and machining techniques.

Discussion

John Reno (Pacific Lumber Co.): How can the problems of knife angle and so forth be handled when a producer planes a variety of species from oak to redwood? Can a quick change be made?

Mr. Petter: Dollars involved for a quick change add about 20 per cent to the cost of the new machine. Designs have been made, but the equipment has not been produced as yet. There are

two ways to handle the problem. First, a cartridge type head and secondly; separate heads.

Richard Vaughn (L. Vaughn Co.): Can carbide be ground as sharp as high-speed steel?

Mr. Petter: It can be ground more sharp.

Mr. Vaughn: What cutting angle do you recommend for both hardwood and softwood machining, that is, redwood and yellow birch, when such machining is done on a given planer?

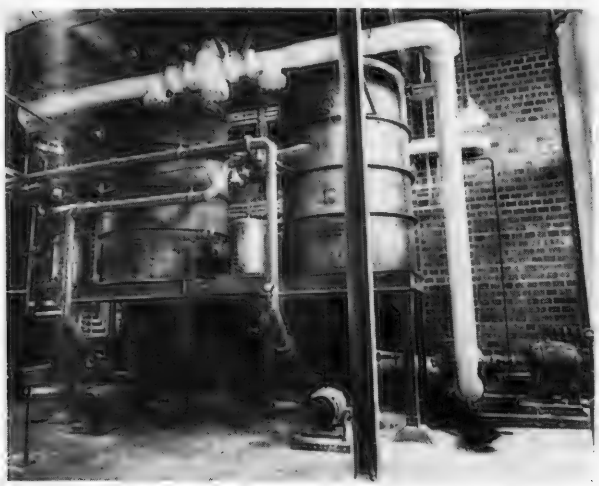
Mr. Petter: I understand the California Redwood Association recommends 20° on dry lumber, 30° on green. We believe 20° cutting angle for yellow birch with a light joint is best.

Mr. Vaughn: Is it possible that there can be any real difference between the quality of the cut when comparing carbide to HSS when machining softwoods and hardwoods? We have experimented along this line and found that we do have a difference but are at a loss as to why and what the cause was.

Mr. Petter: I cannot explain this difference on the assumption that correct grinding practices have been used on both knives. Possibly a light joint on the carbide would be of assistance if your grinder equipment is accurate and rigid.

J. J. Hanssens (H. K. Porter Co.): How much metal is removed when sharpening carbide knives?

Mr. Petter: About 0.002 to 0.004 inch.



Concentrating the stripped liquor by evaporation under vacuum.

Fermenting the liquor continuously in connected vats.

Alcohol Production From Spent Sulfite Liquor[1]

C. A. Watson
Technical Director, Puget Sound Pulp and Timber Co., Bellingham, Wash.

The process consists of recovery of spent sulfite liquor, steam stripping to recover sulfur dioxide, neutralizing with lime, continuous yeast fermentation, distilling the wort, and rectifying and purifying the alcohol.

The Author: Carter Watson graduated from the University of Washington in chemical engineering. He worked with the Wash. State Planning Council on production of alcohol from sulfite liquor, and during the war became project engineer in the U.S. Gov't Synthetic Rubber Research and Evaluation Lab.

AN OUTSTANDING EXAMPLE of the microbiological use of wood components may be found in the production of alcohol from spent sulfite liquor. For over 50 years, the sulfite alcohol industry has used as raw material the wood sugars formed when wood is digested to make sulfite pulp. In the process of digesting the wood, sugars are formed that are subsequently recovered and fermented to produced ethyl alcohol. The sources of these wood sugars can be understood if one reviews some of the reactions that occur during the sulfite pulping of wood.

The sulfite process consists of the treating of wood chips with an aqueous solution of calcium, magnesium, sodium, or ammonium bisulfite at elevated temperatures and pressures. During the pulping process, many simultaneous reactions take place between the wood constituents and the sulfite cooking acid. These complex reactions are not completely understood, but it is believed that hydrolysis of the chemical linkages between the lignin and cellulose molecules takes place. In addition, the lignin is sulfonated and hydrolyzed to make it water soluble. The acid sulfite liquor also hydrolyzes some of the carbohydrates of wood into simple sugars, some of which are fermentable. The carbohydrate hemicellulose are composed of hexose and pentose sugars of which only the hexoses, glucose, mannose, fructose,

[1] Presented at Session XIII, Chemical Utilization, FPRS 12th National Meeting, held June 22-27, 1958, in Madison, Wis.

and galactose, can be fermented to produce alcohol. This wood component is easily hydrolized to yield these sugars.

Upon completion of the pulping process, the wood cellulose is separated from the solution of dissolved lignins, sugars, and inorganic pulping chemicals. This remaining solution is called "spent sulfite liquor" and contains organic substances that amount to over half the weight of the wood. The concentration of the spent sulfite liquor is usually around ten per cent total solids, and contains approximately two per cent by weight of fermentable sugars.

The process of fermenting the sugars present in spent sulfite liquor was first investigated on a large scale in Sweden in 1907 by J. H. Wallin and P. G. Ekstrom. By 1911, three plants had been constructed with an annual production that totaled 660,000 gallons.[2] Six additional plants were built in Sweden in each of the years 1918 and 1919. By 1921, a total of 21 plants were producing in excess of five million gallons annually of 95 per cent ethyl alcohol. Expansion of sulfite alcohol production continued, and in 1940, the world production was over 20 million gallons, with Sweden producing approximately half the total.

During the period of 1948 to 1950, 32 Swedish mills were producing 95 per cent alcohol on a level of approximately 30 million gallons per year. However, in recent years either costs or adverse pricing has brought about a cutback of sulfite alcohol production in Sweden. Operations in 1958 are being conducted by only 20 mills with a total production of about 18 million gallons per year[3].

During the early years of development, all attempts to establish sulfite alcohol plants in the United States and Canada were economically unsuccessful. In 1914, a full-scale alcohol plant was built by the West Virginia Pulp and Paper Co. The operation did not prove to be a profitable one, and the plant was eventually closed. During the years between 1915 and 1920, pilot plant or experimental plant studies were conducted by the Crown Williamette Paper Co. at Oregon City, Oregon, the Kimberly–Clark Corp. at Kimberly, Wisconsin, and the Hammermill Paper Co. at Erie, Pennsylvania. Full-scale production was not undertaken by any of these companies, and further developments did not take place until World War II.

During the second world war, two plants were built in North America: One at Ontario Paper Co. in Thorold, Ontario, with a daily capacity of two thousand gallons of 95 per cent ethanol; the other at Puget Sound Pulp and Timber Co. in Bellingham, Washington, with a capacity of eight thousand gallons daily. Since then, Commercial Alcohols, Ltd. has constructed a sulfite alcohol plant at Gatineau, Quebec, which is similar in size to the Bellingham plant[4]. The operations at Bellingham and Gatineau are continuous, modern in design and equipment, and they use similar processes.

The installation at Bellingham is the only sulfite alcohol plant in the United States, and provides an interesting example of the microbiological utilization of wood sugars. The process consists primarily of five basic operations:

1. Recovery and collection of spent sulfite liquor.
2. Preparation of the spent sulfite liquor for fermentation.
3. Addition of yeast and fermentation.
4. Recovery of the yeast for re-use.
5. Recovery and purification of the alcohol produced.

The process flow diagrams are given in Figs. 1 and 2, and each of the operations that make up the plant will be described separately.

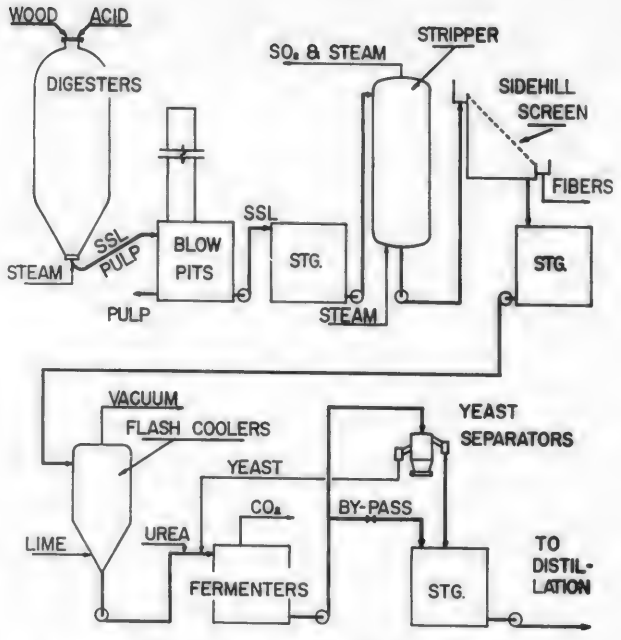


Fig. 1.—Generalized flow diagram for recovery and fermentation.

Recovery and Collection of Spent Liquor

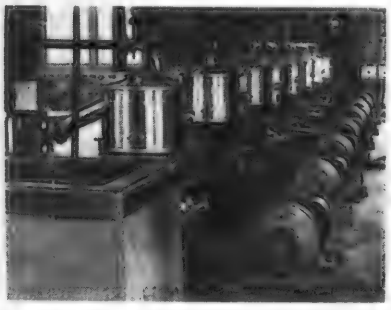
The objective of the first step of the process is to recover as much spent sulfite liquor as possible with a minimum amount of dilution. This aim is accomplished most efficiently by utilizing counter-current washers, but the required space was not available, nor was the capital expenditure justified. In addition, circumstances brought about by wartime conditions dictated the use of existing equipment. A procedure of liquor recovery in the blowpit was devised and has been used satisfactorily for the past 14 years.

The blowpit is first padded (partially filled) with cool spent sulfite liquor; then the digester contents are blown into the pit and the pulp is allowed to settle. The liquor is drained through the false screened bottom of the pit, and water is flooded on the top of the pulp to displace the liquor clinging to the fibers. The draining continues until the wash water suddenly shows in the recovered liquor

[2] Hanson, F. S. 1942 Ethyl alcohol from spent waste liquor, Paper Trade J. CXV (24): 37-40.

[3] Svensk Papperstidning, 1958 LXI (6) 177.

[4] Kure, A. R. 1957. Ethyl alcohol from spent waste liqour. Can. Jour. Chem. Eng. 35:86-90



Yeast is recovered by these centrifuges, which are very similar to cream separators.

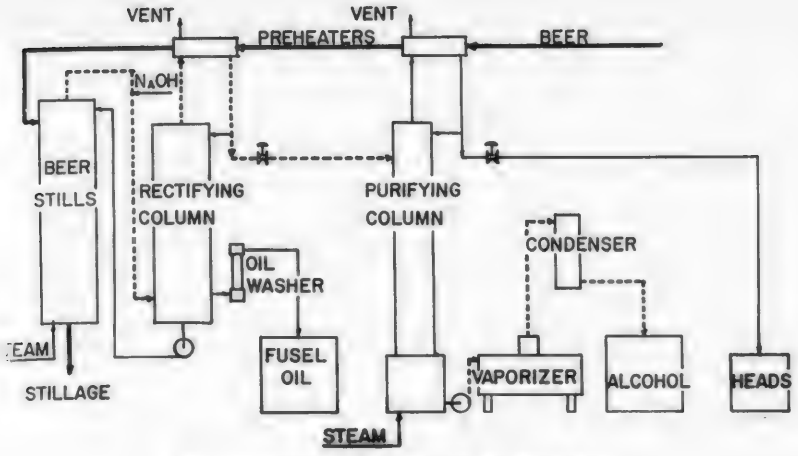


Fig. 2.—Generalized flow diagram for distallation.

whereupon the temperature drop automatically closes the recovery valve and stops the process.

Through this process, over 85 per cent of the liquor solids is recovered. Approximately 2,000 gallons of spent sulfite liquor are recovered per ton of pulp. The liquor contains in excess of 120 grams per liter of total solids. The spent liquor contains approximately 0.2 per cent free sulfur dioxide, 0.4 per cent of loosely combined sulfur dioxide, and 1.8 to 2.2 per cent of fermentable sugars.

The recovered liquor is then pumped to a storage tank and part of the liquor is cooled and returned to the blowpits for padding. The spent sulfite liquor must then be treated to make fermentation possible.

Preparation of Spent Liquor for Fermentation

The spent liquor obtained from the blowpits contains sulfur dioxide, which is toxic to the yeast used in fermentation. In addition, the yeast cannot subsist under the conditions of high temperature and high acidity of the liquor. Therefore, the steps in preparing the liquor consist of stripping the sulfur dioxide from the liquor and cooling and neutralizing the stripper effluent.

The stripping is accomplished by steam in a plate-type column. The liquor and steam flow are counter current for maximum efficiency and economy. The sulfur dioxide is withdrawn from the top of the column and is recovered for reuse in the pulping process. The column is approximately eight feet in diameter by 45 feet in height. It has 20 plates and is constructed entirely of stainless steel. The design is typical of a sieve-plate stripper with adequate plate spacing for a man to enter and clean off scale deposits.

The column is equipped with automatic controls. The liquor is pumped from the stripper over side-hill screens to remove pulp fibers. From the screens, the liquor flows by gravity into the hot liquor storage tank. The liquor is then cooled as it enters the alcohol plant.

The liquor is cooled by evaporation under vacuum. This process concentrates the liquor to about 12 per cent, and at the same time eliminates additional amounts of sulfur dioxide. The equipment consists of two flash tanks, each with spray eliminators, barometric condensers, and steam ejectors for producting a vacuum. The flash chambers are about eight feet in diameter and 15 feet high. The liquor enters tangentially near the top, spins around the walls, and is pumped from the conical base. The first flash chamber operates at a vacuum of 25 inches of mercury. The liquor enters at 105° C. and leaves at about 50° C. This liquor is then pumped to the second flash chamber, which operates at a higher vacuum, where it is cooled to approximately 32° C. The liquor acidity is adjusted at the base of the second cooling chamber to a pH of 4.5 by adding lime. The conditioned liquor is then pumped directly from the coolers to the fermenters.

Fermentation

Fermentation is carried out continuously in seven interconnected fermentors of 80,000 gallons each. Each fermentor is equipped with an agitator for mild agitation and a vent pipe for carbon dioxide. Yeast and ammonia or urea are proportionally added to the liquor entering the first fermentor. The liquor over-flows from the first into the second and so on through to the last fermentor. Approximately 95 per cent of the fermentable sugars are utilized in the 15 to 20 hour cycle. The yeast used for producing alcohol is the baker's variety, *Saccharo-myces cerevisiae,* and amounts to a total quantity of about 25 tons of wet yeast in the fermentation system or about 0.2 per cent on the basis of dry solids. The yeast is acclimated to the spent sulfite liquor, and enough nutrients are added to keep the yeast growing continously as the old cells die. The yeast is recovered by centrifuging at the end of the cycle and returned continuously to the fermentors.

Recovery of Yeast

The separation of the yeast from the fermented liquor is accomplished in eight stainless steel centrifuges. These machines are very similar in construction to cream separators. Liquor from the last fermentor is pumped to a head tank, which splits the flow evenly between the centrifuges. The fermented liquor contains about one per cent yeast by volume and is separtaed into two streams, one containing 15 per cent by volume, which is returned to the system, and one clear liquor stream, which flows into beer storage prior to distallation. Part of the fermented liquor is by-passed around the centrifuge to the beer storage. This process provides a continuous purge of dead yeast and insoluble solids that would otherwise eventually overload the centrifuges. The liquor is then pumped from the beer storage to the distillation plant.

Distillation

Alcohol is recovered from the fermented spent sulfite liquor by steam stripping which is accomplished by

Alcohol is stripped from the beer in the first two of a 5-column distillation process.

concentrating and purifying in a five-column distillation process. The beer or fermented liquor contains approximately one per cent of alcohol, and large quantities of steam are required to strip the alcohol from the beer. The stripping is accomplished in much the same manner as previously described for the removal of sulfur dioxide, except that two stills are operated in parallel. The alcohol vapors leave the top of the still at a concentration of approximately 25 per cent. The vapor overhead from the first two stills is introduced into the base of the third still, or rectifying column, where further concentration of the alcohol occurs and any traces of fusel oil are removed. The fusel oil accumulates on the mid-column plates and is withdrawn as a side stream. It is then washed, decanted and discharged for storage. About 25 gallons of fusel oil are produced daily.

Concentrated alcohol from the rectifying column is fed to a purifying column, where approximately 250 gallons of methanol is separated per day from the alcohol. The overhead distillate from this column contains this methanol along with other volatile components, and is condensed and discharged to storage. The purified alcohol is discharged from the base of the column and flows to the final vaporizer.

The alcohol is chemically treated as required in the base of the final kettle still. The purified 190 proof ethanol is then vaporized, and the cooled condensate is accumulated in alcohol storage.

Special Precautions

Fermentation processes of any type require special precautions, such as sterile conditions to prevent contaminations by wild yeast and bacteria, and close regulation of temperature and pH.

Steps are also taken to assure a high-quality ethanol by chemically treating the product. Since impurities may vary, it is necessary to vary also the special treatment of the final product.

The nature of the raw spent sulfite liquor demands that special precautions be taken during the construction of an alcohol plant. All materials in contact with the liquor or its vapors must be corrosion resistant. The methyl alcohol fraction is particularly corrosive. Certainly the job of constructing and operating a sulfite alcohol plant is not as simple as might appear at first. In addition to these technical problems, the manufacturer is also concerned with the markets for his product, that is, where and how much alcohol is used.

Markets and Competition

Ethyl alcohol is widely used in industry as a solvent and as an intermediate process material in making over 200 chemical compounds. In fact, over one thousand uses have been listed for industrial alcohol[5]. Prior to World War II, the consumption in the U. S. amounted to approximately 100 million gallons annually. The ethanol requirements, during the war, for synthetic rubber and various war uses raised the requirements in 1945 to an unprecedented 600 million gallons[6]. Shortly thereafter, the consumption was reduced by about half when technological developments eliminated the use of ethanol in the manufacture of butadiene for synthetic rubber. Since then, new demands such as in the field of rocket propellants have again increased the demand to a figure of 500 million gallons per year. The mixture of ethyl alcohol and liquid oxygen is one of the most powerful liquid propellants now in regular practical use.[6]

With the large number of uses and with consumption at the half-billion gallon mark, it would appear that there would be no sales problems. This is not the case, however, for there are a great number of manufacturers of ethanol competing on the basis of quality and price for the same market. No less than 20 sources of raw materials are used for producing alcohol, with the main ones being molasses, grain, potatoes, and petroleum hydrocarbons. Molasses once was traditionally the low-cost material, and large fermentation industries were located on the Atlantic and Gulf Coast with operations based on cargo shipments of molasses from the cane sugar areas. For many years, the manufacture of industrial alcohol was so dependent on molasses that any changes in price of the raw material were reflected in rather sharp and drastic price changes for alcohol. The stabilizing influence of synthetic ethanol has entered the picture in recent years, and has smoothed out these price fluctuations.

Synthetic alcohol produced from ethylene is now the most important single factor to influence industrial alcohol production. During 1947, the synthetic production equalled that from molasses, and by the end of 1956, over three-quarters of the industrial alcohol was produced synthetically.[7] A comparison of manufacturing costs between the different processes reveals that synthetic ethanol is the cheapest, with ethanol from molasses and grain next in order.

With the cost of producing ethanol from spent sulfite liquor acknowledged to be higher than synthetic ethanol costs, one can easily see that the future of the sulfite alcohol industry is dependent upon the continuance of prevailing markets and prices. If either the volume of sales or the prices were to revert to pre-war figures, alcohol manufacture from spent sulfite liquor would not be a competitive or economically feasible process.

These economic considerations in the United States are undoubtedly responsible for the lack of development of manufacturing facilities, based on the microbiological utilization of wood sugars, to produce alcohol. For, after 50 years of experimental research and practical use, the technology of the process is well developed and understood.

Discussion

J. R. Salvesen (Marathon): What is the primary reason for the poor competitive situation for alcohol from spent sulfite liquor particularly in view of the fact that there is no raw material cost, as contrasted to alcohol from molasses or grain?

Mr. Watson: The primary reason is the low concentration of alcohol obtained, and the consequently high cost of stripping and rectification.

J. M. Sayward (Vermont Bureau of Industrial Research): What chance is there of a completely different method (than evaporation) for separating and concentrating the sugars, such as adsorption (activated carbon, silica gel, cellulose, etc.) on exchange, or even solvent extraction?

Mr. Watson: Various methods have been studied, but to date none appears practical for the sole purpose of separating and concentrating sugars.

H. N. Calderwood (Consultant): What happens to the beer slop?

Mr. Watson: First, the heat is recovered from the slops, then the fermented spent sulfite liquor serves as a basis for our firm's lignin by-product business. The remainder is discharged to the sewer.

Mr. Calderwood: Do volatile oils from wood cause difficulties?

Mr. Watson: Not particularly. Some oils show up on the plates of the distillation columns.

Mr. Calderwood: What species of wood are pulped?

Mr. Watson: A mixture of hemlock and white fir.

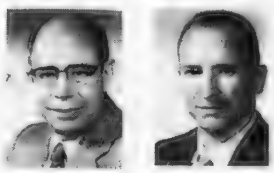
[5] Gregory, T. C., 1939. Uses and applications of chemicals and related materials, Reinhold Publishing Co., New York.

[6] Kirk, R. E., and Othmer, D. F. (ED) 1947. Encyclopedia of Chemical Technology, Interscience Encyclopedia, Vol. 1, New York.

[7] U. S. Bureau of the Census. Statistical Abtract of the United States: 1957 (Seventy-Eighth Edition) Washington, D. C.

Developing the *Best* Resin for the *Particular* Process[1]

C. M. Keaton and R. E. Beyer
Adhesive, Resin, & Chemical Division, American Marinette Co., Seattle, Washington



"Specific resins for specific processes" summarizes both past and present resin development. Factors involved are: the board product, resin characteristics, and resin manufacture.

SYNTHETIC RESINS CAME INTO USE in the wood composition board industry in answer to the need for supplementary bonding, that is, bonding in addition to that obtained through natural bonding forces. This is clearly illustrated in the story of the Western Wet Process for manufacturing hardboard. Initially, practically all hardboard was made by the Masonite and U. S. Gypsum processes, in which bonding is achieved through the use of the natural compounds contained in the wood. The Western Wet Process was developed to meet regional requirements for economical, relatively small hardboard plants. In this process, the mechanically formed fiber is put in a water slurry, formed into mats, freed of excess water, and hot pressed. Hardboards made by this procedure had mediocre strength properties. Supplementary bonding was required. Cooperative research between the board and resin manufacturers led to the development of a specific resin binder for use in this process.

"Specific resins for specific processes" is the story of both past and present resin development. This is emphasized by the fact that at the present time practically every dry-process hardboard plant is using a different resin. The development of such specific products by the resin companies involves consideration of many factors, including those concerned with the board and its process of manfacture, the available resin raw materials and technology, and the economic limits.

An actual resin-binder development program involves an evaluation of the composition board with respect to product requirements, wood raw material, and the processing conditions. Based on this information, certain resin characteristics are selected. The resin is then tailored to have these properties through proper formulation and processing.

A list of some of the factors that must be considered in a resin development program follow:

Factors Involving the Wood Product

1. Wood Raw Material: a. species (pH, density, and so forth); and b. other (moisture, bark content, and so forth.)
2. Board Product Specifications: a. physical properties; b. environmental durability; and c. cost.
3. Board Processing Conditions: a. fiber or particle preparation; b. fiber or particle carrier (water, air, and so forth); c. resin and additive addition (method, place); and d. formation and pressing conditions.

Factors Involving Resin Characteristics

1. Durability
2. Cost
3. Storage life
4. Dilutability
5. Precipitability and retention
6. Ease of distribution (sprayability, viscosity)
7. Bonding efficiency
8. Cure-flow relation (under use conditions)
9. Color
10. Odor
11. Acidity or alkalinity

Factors Involving Resin Manufacture

1. Type and number of raw materials
2. Ratio of reactants
3. Concentration of reactants in solvent
4. Solvent composition
5. Type and ratio of catalyst
6. Type and ratio of modifiers
7. Time-temperature processing cycle
8. Order and rate of addition of ingredients

As indicated by these lists, there are a large number of variables and, as a result, an even greater number of combinations of variables. By way of illustration, even with all the work that has been done in the resin field to date, it would be possible to go into the lab tomorrow and make a new resin, one with new and different characteristics. In addition, the list of resin raw materials is steadily growing and new resins other than ureas, phenolics, and melamines, resins such as urethanes, alkyds, polyesters and epoxies, are being investigated.

Interrelations have been worked out between known "board factors" and "resin characteristics" and this does make it possible to tailor-make resins. The all-important selection of resin characteristics, however, is limited by the accuracy and completeness of knowledge of the limiting board factors.

For example, how durable should a particle board be with respect to environmental heat and humidity conditions? What test should be used to evaluate this property? As an illustration, phenolic resin-bonded particle boards will retain approximately 30 to 60 per cent of their original strength, depending upon original board characteristics, according to the ASTM accelerated aging test, D-1037-52T, while boards bonded with urea resin will disintegrate in the third or fourth cycle of this test. On the other hand, the actual water absorption and per cent thickness swell values obtained in a water soak test are as great or greater for a phenolic board than for a similar urea board.

In an attempt to answer this particular question, the American-Marietta

[1] Presented at Session X, Wood Composition Board (2), PFRS 12th National Meeting, June 22-27, 1958, Madison, Wis.

Co. has recently investigated a new test for evaluating particle board environmental durability. This test involves heating samples of the resin-bonded boards at a specific temperature for a definite period of time under dry and humid conditions. A comparison is then made between the strength properties of these samples after the heating cycle with the original values. Results obtained by this test from laboratory boards made with six different resin binders are shown in Table 1.

Table 1—EFFECT OF HEAT TREATMENT

Particle board modulus of rupture and edge screw holding values as percentage of original.

Resin	MOR		ESH	
	Dry	Humid	Dry	Humid
A	97	101	100	97
B	89	43	89	52
C	89	40	88	42
D	88	45	95	55
E	89	40	91	46
F	78	37	94	51

In this particular experiment, the board samples were heated for 14 days at 200°F, both dry and at 25 per cent relative humidity. Resin A was a phenolic, resin D a furfuryl alcohol modified urea, and all the others were unmodified urea resins.

The test is of particular interest because it: 1. subjects the particle board binder to conditions of the type that it may meet in general use; 2. shows differences in the deterioration of urea resin binders under dry and humid heating conditions; and 3. places all resins on a scale with respect to strength retention and thus offers a chance of showing differences between resins.

The above study suggests the correlation of board and resin durability. Additional examples that illustrate the correlation of board factors and resin characteristics are brought out by discussing differences that exist between wet, semi-dry, and dry hardboard processes. Phenolic resins are used in all three operations.

The wet process, first of all, requires a highly condensed phenolic resin; one that can be precipitated from a water-resin-fiber slurry to give a high retention on the fiber. The resin in this process is also subjected to a very high pressing moisture content, approximately 100 per cent. This again calls for a highly condensed resin to give optimum cure and flow characteristics.

Resins for the dry and semi-dry processes are often added to the fiber by spraying. This calls for a resin that can be sprayed easily to give maximum distribution; possibly one that has a high water dilutability, which would allow for dilution so as to give even greater distribution. Resins for these processes must also be adjusted to give optimum flow and cure. The dry process, which requires a very low pressing moisture (around 10 per cent) requires a relatively low condensed resin. The semi-dry process with an intermediate pressing moisture (30–40 per cent) calls for a resin intermediate in condensation as compared to the dry and wet processes.

The correlation of board and resin factors could be further exemplified in a discussion of differences between hardboard and particle board processes. For example:

Particle Board—Either urea or phenolic resins can be used in particle board. In hammermilled planer-shaving type board at the normal density of 41 lb. per cubic foot and under laboratory controlled conditions, 6 per cent usage of either of these resins gives maximum strength.

Hardboard—In general, only phenolic resins are used in hardboard. In wet-process hardboard, ½ to 2 per cent of resin is used, while often higher strength could be obtained through the use of up to 3 or 4 per cent of resin.

A thorough discussion and explanation of this situation would involve every resin characteristic listed under "Factors Involving Resin Characteristics."

Precise adjustments of resin characteristics by resin formulation and processing yields the so-called tailored resin. In the tailoring operation, as stated earlier, there are many resin manufacturing factors to be considered and controlled. How is this done? Condensation or advancement of a phenol-formaldehyde resin, for example, may be varied in a number of ways. High advancement can be obtained by long, high temperature processing, usually in the presence of an excess of some alkaline catalyst such as sodium hydroxide. The use of high formaldehyde to phenol molar ratios also tends to give high resin advancement. Specific degrees of condensation, high or low, are achieved through exact control of these and many other factors.

With respect to the use of caustic, interactions with factors other than advancement come into play. For example, the use of a high caustic content resin in dry-process hardboard would produce a board with both high water absorption and thickness swell values. The resin must be tailored to give optimum results with respect to all of these factors.

Another example of resin processing to meet certain conditions is the use of modifiers to minimize the odor of formaldehyde in urea resins, such as are used in particle board. Formaldehyde odor may also be controlled by proper control of the time-temperature cycle in resin processing.

As a result of this trend to tailored resins, many new and specific resins are continually being developed. This point is emphasized by the fact that, of 12 of the American-Marietta resins currently being offered for use in the composition board industry, 10 were developed in the last three years and eight of these in the last year and a half.

The future of resins in wood composition boards and similar products depends, as did their initial entry into this field, on their answering specific needs. These needs are, to be sure, associated with old as well as new products and processes. The problem, however, is to find them and define them. Research of this type has incentive for both the board manufacturer and the resin manufacturer.

Discussion

K. N. Stordalen (Wynnewood Products Co.): When you mentioned maximum of 6 per cent resin were you referring to urea or phenolic?

Mr. Beyer: I referred to both urea and phenolic resin applied to planer shavings.

Mr. Stordalen: Wouldn't there be a difference?

Dr. James d'A. Clark (Changewood Corp.): I should like to clear up once and for all the confusion regarding dry and semi-dry or wet process boards. If air is used to deposit the elements, whether they are dry or moist, the process is "dry"; if water is used as the vehicle for carrying the elements, the process is "wet". One can also have a dry process, moist filler, with a wet or dry pressing, also a wet process with a wet or dry pressing. A "dry" process, without qualification should mean an air-deposited, dry fiber, with a dry pressing; a wet process, a water deposited (wet) fiber and wet pressing. For example, a smooth-two-sides hardboard is either dry-processed, dry-pressed if air-laid from moist fibers, or is wet-processed, dry pressed, if water laid.

Max Yan (Abitibi Power & Paper Co.): How were the temperatures chosen for the aging test you reported? Do you feel that the temperature used would correspond to the temperature under a roof, for example?

Mr. Beyer: The temperature selection was arbitrary. We were after a rapid test for evaluating our products, and possibly the temperature used may not be completely realistic. This test could be adapted, however, to evaluate the effect of specific temperatures.

WORLD-WIDE

Forest Products News

World Lumber Production Down, Derived Products Up in 1957

World Situation, 1957

THE WORLD TIMBER HARVEST IN 1957 was slightly less than in either of the two previous years, although still a respectable 1,587 million m³. The 1956 roundwood removals turned out to be higher than the preliminary figures in the 1957 *Yearbook* indicated.

North America again reported the largest volume of fellings, followed by the U.S.S.R. and Europe. The 1957 figures were higher than those of the previous year in Asia, Europe, Africa, and Central America, lower in North and South America, and the same in the Pacific Area.

A break-down of the roundwood removals in each region is shown in Table 1.

Table 1 is not a completely accurate picture, because large volumes in all regions are harvested by local inhabitants for their own use, and do not appear in the statistics. These unrecorded and unreported volumes are mostly in fuelwood and in the "other industrial wood" categories, the latter consisting of poles, piling, posts, and so forth.

During the 10-year period 1948–1957, the proportion of roundwood in the various categories has undergone considerable change. As the forest products industries have developed, their increasing demands on wood raw materials are reflected in the statistics. Thus, Europe has increased its consumption of pulpwood, while the relative (as well as actual) volume of fuelwood has decreased. In the U.S.S.R., the share of total removals harvested for sawing and for plywood shows a considerable increase. In North America, the pulp industries have increased most, in terms of wood used. The pulp industries as well as those using sawlogs and veneer logs show strong growth in Asia and the Pacific.

The above is a condensation of the summary from the twelfth *Yearbook*, prepared by the Forestry Division of FAO, in collaboration with the Economic Commission for Europe. The 185-page book is available from FAO, or International Documents Service, Columbia University Press, 2960 Broadway, New York 27, N. Y., for $2.50.

Forests in World Economy

A rough calculation of the value of world forest products is shown in Table 2. In spite of the difficulties of arriving at average unit values on a global basis, this table does show something of the magnitude of the timber harvest in value terms, and an indication of the direction of change that has taken place between the years 1956 and 1957.

It should be recalled that the values represented by forest products other than wood (seeds, nuts, rubber, cork, tanbark, gums, bamboo, reeds, and so forth) are not included in Table 2.

World Trade in Wood Products

This issue of the *Yearbook* gives for the first time a detailed breakdown of the value of exports and imports by the main types of wood products. The greatest total export value in 1957 was in coniferous sawnwood (U. S. $1,137 million). Broadleaved species, however, have a considerably higher value than the coniferous in the sawlog and veneer log group, largely because of the importance of the tropical hardwood trade. The total value of exports of pulp products (paper, paperboard, and fiberboard) reached nearly U. S. $1,856 million.

In terms of the roundwood equivalent of total forest products exports, the leading region is Europe, with 77.9 million m³. The highest percentage of industrial wood removals entering international trade in 1957 was in Africa (43%, Table 3).

The figures in Table 3 include both intraregional and interregional exports; therefore, the regional position with respect to forest products trade is somewhat better shown by the net trade balances (in roundwood equivalents of all forest products exports and imports) of Table 4.

The values in Table 4 include some of the manufactures of forest products, so its scope is somewhat greater than that of the "primary" forest products industries. The figures show that the trade values continue to climb. From the year 1956 to 1957, the greatest value gain, 6.5%, was shown by paper and paperboard exports; wood and cork gained 2.5% in total value of exports; pulp and waste paper remained steady, and the group "wood lumber, and cork" lost about 0.5%.

Table 1

Region	Sawlogs, veneer logs and logs for sleepers		Pulpwood and pitprops		Other industrial wood		Fuelwood	
	1948	1957	1948	1957	1948	1957	1948	1957
	Percentage of total removals							
Europe	34	36	16	23	8	7	42	34
U.S.S.R.	24	37[1]	9	10[1]	20	18[1]	47	35[1]
North America	55	53	23	28	6	4	16	15
Central America	14	11		2	1	1	85	86
South America	9	12	1	1	1	1	89	86
Africa	5	8	1	1	1	1	93	90
Asia	17	22	2	7	3	4	78	67
Pacific area	51	56	4	9	3	4	42	31
World	30	34	11	15	8	7	51	44

[1] Year 1956.

Table 2

	1957 Millions of US dollars	1956 Millions of US dollars
Products of sawlogs[a]	14,200	14,600
Products of pulpwood[b]	8,900	8,700
Pitprops	500	600
Other industrial wood	900	1,000
Fuelwood	2,900	2,900
Total	27,400	27,800

[a] Sawnwood, sleepers, veneers, plywood.
[b] Paper, paperboard, fiberboard, particle board.

Table 3

Region	Industrial wood exports[a] as percentage of removals
Europe	39
U.S.S.R.	3[b]
North America	17
Central America	10
South America	15
Africa	43
Asia	8
Pacific area	6
World	18

[a] Forest products in terms of roundwood equivalent.
[b] Year 1956.

Table 4

Region	Net balance[a] 1957 Million m³ (r)	Net balance[a] 1956 Million m³ (r)
Europe	— 5.3	— 1.4
U.S.S.R.	+ 7.2	+ 4.2
North America	+10.4	+ 7.5
Central America	— 0.9	— 0.7
South America	— 3.2	— 3.1
Africa	— 0.1	— 0.1
Asia	— 3.0	— 2.1
Pacific area	— 2.1	— 2.4

[a] Exports +; imports —.

Wood Products Production

Sawnwood: The world picture for sawnwood is one of steadily increasing volume from 216 million m^3 at the beginning of the decade to a peak of 296 million in 1955, followed by a decline to 283 million this past year. Comparing production figures for 1957 with those of 10 years ago shows annual sawnwood output has increased in the U.S.S.R. by 46.3 million m^3, in Asia (estimated) 19.9 million, in Europe 7.1 million, and smaller amounts in South America and Africa. Declines were registered in North America (–9.1 million) the Pacific Area and Central America. From the 1956 to 1957, world production went down 4%, but in North America the decrease was 12%. Declines were also registered in South America (5%), Europe (3%) and the Pacific Area (1%). Increased production was reported from Asia (6%), U.S.S.R. (3%), Central America (3%), and Africa (2%).

Plywood: A recent FAO review of plywood production and marketing trends shows a steady but gradually weakening growth in output since the prewar years. The 4% increase from 1956 to 1957 was one of the smallest of the decade. World production still set a new record at 11.7 million m^3. North American production, which constituted 58% of world output, increased only 1% during the past year. The European countries had 18% of world production, while Asia and the U.S.S.R. each had 10%. For the 1948–1957 period, the production of Asia shows the greatest growth, more than sevenfold. Output in each of the major producing regions more than doubled: the 1957 volume in the U.S.S.R. was nearly 2.7 times that of 1948, in North America 2.5 times, and in Europe 2.4 times. Japan has emerged as the third largest producer (946,000 m^3) after only the U. S. (6 million m^3) and the U.S.S.R. (1.2 million m^3).

Pulp: The volume of wood pulp produced annually in the world as a whole continued to climb, reaching a total of 50.1 million tons in 1957, even though North American production fell from 29.8 million tons in 1956 to 29.2 in 1957. Thus, the rapid increase that has been characteristic through most of the decade was slowed. The 10-year growth, however, has exceeded forecasts, and the outlook is for continued expansion.

Pulp Products: Every year of the present decade has marked a new record in newsprint production. The year 1957 was no exception: the total world output of 12.35 million tons was an increase of almost 3% over that of the previous year, though short of the 8% rise of the year before.

The general category listed as "paper other than newsprint" in both years (1956 and 7) consisted of about 35% printing and writing paper, the rest being a variety of wrapping, tissue, industrial, and other papers. Except for a slight decrease in 1952, production has grown steadily throughout the decade to the 1957 record level of over 28.5 million tons.

World production of paperboard reached a new record level in 1957. Of the total of over 20.4 million tons (2% above the previous year), about two thirds came from North American mills. European countries produced over 4.3 million tons, Asia about 1.3 million, and other regions lesser amounts.

The fast-growing fiberboard industry also set a new production mark, a total of nearly 3.4 million tons in 1957, which is a small increase over the previous year. In spite of the rise in fiberboard production, its share in the output of all pulp products has been nearly the same throughout the decade.

Particle Board: The reports on particle board production and trade continue to be sketchy, and little can be said about this growing forest products industry beyond that already published by FAO in its recent comprehensive report. European production constitutes about 70% of total world output, with the Federal Republic of Germany the center of the industry. The volume of production in France has expanded appreciably since 1956.

Other Developments Around the World

Fifth World Forestry Congress to be held in Seattle

How to manage the earth's forest resources will be the chief topic of discussion at the Fifth World Forestry Congress to be held Aug. 29–Sept. 10, 1960 at the University of Washington in Seattle.

The organizing committee of the Congress, of which Society President Eason is a member, met recently in a 2-day session at the State Dept. in Washington. The committee made plans to set up programs and accommodations for foresters and related scientists who will attend.

More than 1,200 foreign and domestic participants are expected to attend. Delegates to the congress will have several regional tours they can take, each designed to give a cross section of forestry activities in a particular section of the United States. A series of shorter local forestry tours near Seattle is planned as part of the congress.

More information about the congress may be obtained from Dr. I. T. Haig, Executive Secretary, Fifth World Forestry Congress, Dept. of State, Washington 25, D. C.

Forest Products Publications Scanning World Wide

Studies on the Effect of *Merulius lacrymans* (Wulf.) Fr. and *Coniophora cerebella* Pers. on the Mechanical Properties of Wood. Jerzy Wazny. *Holz a. R. uW.* V. 16, No. 8. (In German)

The effect of *Merulius lacrymans* and *Coniophora cerebella* on the loss of crushing strength, static bending strength, impact bending strength, and Janka-hardness of pine (sap- and heartwood), spruce, beech and oak was investigated.

The impact bending strength was found to decrease most of all, followed by bending strength, crushing strength, and hardness. All mechanical properties were more affected by *Coniophora cerebella* than by *Merulius lacrymans*, excluding the hardness, which was equally influenced by both fungi. The highest resistance to the strength-decreasing effect of the fungi was shown by oak, followed by pine heartwood. Pine sapwood, spruce, and beech were less resistant.

Rationalization in the Woodworking Industry by the Use of Double End Tenoning Machines. Hans Düwer. *Holz a. R. uW.* V. 16, No. 8. (In German)

The paper describes the possibilities for rationalization in the woodworking industry offered by the use of automatic double-end tenoning machines. The different operations that can be executed in a single passage because of the versatile applicability of these machines are demonstrated with several examples.

CORRECTION

In the November issue of the FOREST PRODUCTS JOURNAL ("Around the World" section, p. 41-A) appeared a significant letter-discussion on the swelling behavior of wood, by Prof. Yu. M. Ivanov. Two editorial errors have been noted. Figs. 1 and 2 were interchanged, and it was not indicated that the two upper curves in Fig. 1 (mislabeled Fig. 2) are for air-dry wood and the two lower curves for wet wood. Perhaps it should also be noted that the descriptive phrase, "A Russian's Theory on" was added by the editor.

Quantitative Determination of the Chromium and Arsenic Content of Impregnated Poles by the Activation Analysis. W. Reusse and R. Zaublitzer. *Holz a. R. u. W.* V. 16, No. 8. (In German)

Methods are described that make it possible to examine wood impregnated with preservative salts as to the amount injected and the composition of the treating solutions. The methods are based on the activation of the preservative salts and the wood in the atom pile by neutron shooting and the measuring of the subsequently emitted rays with a Geiger counter to determine half-life and radiation energy.

New Kiln Design. V. Iliescu. *Industria Lemnului.* (Romania) V. VII, No. 12. (English summary).

The new kiln types presented in the article will enable by their design the application of high-intensity drying schedules. They comprise: kilns in the lengths of 8.5 m and 12.5 m, a lumber drying tunnel, and a parquet-strip drying tunnel. A description is given of the operating conditions of these installations, followed by technical data and details on the respective productivities.

The Effect of Peeling Speed on Veneer Yield and Quality. S. Nivin. *Industria Lemnului* (Romania). V. 7, No. 12. (English summary).

The article analyzes the problem of the peeling speed of rotary lathes now in operation in plywood factories, and, in connection with this, the establishment of maximum speed for the peeling of beech logs as well as the raising of rotary lathe yield by increasing the peeling speeds.

New FAO and International Publications

General Catalogue, 1958. Contains a listing of publications put out by the Organization for European Economic Cooperation from 1948 to 1958. It contains a section on timber and paper industries with listings covering wood research in Europe, materials handling of timber, drying and conditioning of timber, and others. Available from the OEEC Mission, Suite 1223, 1346 Connecticut Ave., N. W., Washington 6, D. C.

The Growth of Forest Industries and Their Impact on the World's Forests. Food and Agriculture Organization of the United Nations. Reprint from the *The State of Food and Agriculture 1958.* Available from FAO, Vialle delle Terme, Rome, Italy.

"Briefing" FPRS Papers

Condensations of Selected Section and National Meeting Papers

Air Pollution Abatement

R. O. Blosser, Resident Engineer, National Council for Stream Improvement, Inc. Presented at Session XV—Chemical Utilization (2), FPRS 12th National Meeting, June 22–28, 1958, Madison, Wisconsin.

The National Council for Stream Improvement is supported by the pulp, paper, and paperboard industry for the purpose of developing solutions to the industry's waste disposal and utilization problems. It carries out wide activities in the field of stream pollution. In addition, a study of the pulp and paper industry air pollution problem was initiated recently.

While air pollution problems in the paper industry are not of the magnitude of the stream pollution problem, increased legislative activity in recent years indicates the increased interest of the public in this field. Since little was konwn concerning the characteristics, composition, or mechanics of dispersion of air-borne effluents from the paper industry, an atmospheric study program was instigated some two years ago by the National Council.

The problems involved in air pollution are not so well defined as many of those in stream pollution. Research to date has dealt almost entirely with the air-borne effluents from Kraft pulping operations with the investigation of particulate matter from fuel burning only recently being undertaken.

Identification and measurement of air-borne effluents, their continuous sampling and analyses both at the stack and in the air is the primary task of research projects established at the University of Florida and the University of Washington. A recently instituted project at New York University will deal with stack effluents from fuel burning as practiced in pulp and paper mills.

A recent survey covering 58 Kraft mills has classified the sources of air-borne effluents into three categories: 1) pulp mill sources; 2) chemical recovery plant sources, and 3) auxiliary power generation sources. While precise identification of the air-borne effluents has not been completed, hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide are known to exist in the gaseous effluents.

The digestion process is an important source of these gaseous, odorous, effluents and another the recovery stack losses. Minor stack losses occur in component parts of the pulping process. Reduction of emission of these compounds from the digestion process is accomplished by turpentine recovery, burning, the use of jet condensors, oxidation, and absorbtion with caustic compounds.

The use of odor-masking compounds has met with mixed success. Methods used to abate odors from chemical recovery include scrubbing of evaporator non-condensibles with black liquor or caustic, air oxidation of black liquor to oxidize the reduced sulfur compounds to more stable compounds, and the use of odor-masking or catalytic-reactant compounds.

Aerosols and particulate matter are discharged in the chemical recovery process. Sodium salt fumes are lost in the stacks of recovery furnaces, even though most mills employ precipitators to recover the bulk of these. The most common recovery equipment is the electrostatic precipitator designed with a recovery efficiency of 90–95 per cent, while some Venturi scrubbers are used for sodium salt fume recovery. These obtain efficiencies of 85–90 per cent.

The primary sources of particulate matter emission are the lime kilns, auxiliary power equipment, and bark burners. Lime kilns are usually equipped with wet scrubbers for recovery of particulate matter. Some fine particulate matter escapes collection equipment on bark boilers, and fly ash may be a problem where coal is burned.

While recovery equipment on black liquor furnaces and lime kilns is now considered part of the process, nevertheless the use of this equipment greatly reduces the material discharged to contaminate the air. In many mills, the use of dust and fly-ash collection equipment to prevent air pollution is a common practice. It has been shown that about $1,000 per ton of productive capacity has been spent on equipment and processes that result in decreased air pollution from Kraft mills.

Stream Pollution Control in Wisconsin

Theodore F. Wisniewski, Director, Wisconsin Committee on Water Pollution. Presented at Session XV—Chemical Utilization (2), 12th National Meeting, June 22–28, 1958, Madison, Wisconsin.

Wisconsin Statutes authorize the Committee on Water Pollution to enter into cooperative studies of industrial wastes with representatives of industrial groups. Such studies have been conducted in cooperation with the Canners' Assoc., the Advisory Committee on Waste Disposal of the Wisconsin Pulp and Paper Industry and the Sulphite Pulp Manufacturers' Research League.

Annual mill waste surveys, conducted in cooperation with all the pulp and paper mills in Wisconsin, have proved effective in reducing fiber losses from mills to one-third of what they would have been had there been no such program. Wisconsin is the only state that conducts such a program in cooperation with its pulp and paper mills.

The Sulphite Pulp Manufacturers' Research League originally explored all methods of treatment of spent sulphite liquor, and concluded that methods for utilization of the spent liquor would prove more practical. For each ton of pulp produced, about one ton of solids is contained in the spent liquor that was formerly discharged directly to the streams. Thus, half of the wood was not being utilized, and the League proceeded to conduct studies to determine methods of recovering or utilizing these solids.

One of the first methods developed was that of aerobic fermentation in specially designed equipment, which used a controlled process for production of yeast that could be utilized as an animal food. Today there are two full-scale plants, one at Rhinelander producing 14,000 pounds of yeast per day, and one at Green Bay designed to produce 28,000 pounds of yeast per day.

Early yeast marketing problems led to studies of evaporation and burning as a means of spent liquor utilization. In this process, the liquor is concentrated to about 55 per cent solids and burned in boilers to produce steam with a saving in other fuels. Evaporation and burning plants have been installed at Appleton, Green Bay, and Rhinelander.

Soil filtration of spent sulphite liquor is practiced at other mills in the state, and the League has been conducting careful studies of this method. One other method is to use the liquor for conditioning earthen roads, and this too is being studied by the League.

In connection with cooperative programs, the Committee has, for many years, supplied to certain mills the equipment and reagents necessary for studies of streams that receive their wastes. Samples are collected by mill personnel, and the results of analyses are tabulated so that information is available on the actual condition of these streams during the critical summer periods. This information is used to demonstrate whether or not the corrective measures taken are actually resulting in stream improvement.

The present trend in water pollution control is to continue to demand higher and higher degrees of treatment, because growth of communities and industries will increase the need for more and more clean water. The pulp and paper industry has accomplished high reductions in fiber losses and about a 50 per cent reduction in pulp mill pollution. A number of other industries have also cooperated in the program for cleaner streams.

White-Pocket Fir for Plywood

Research conducted by the U. S. Forest Products Laboratory in cooperation with the Douglas Fir Plywood Assoc. has shown "white pocket" timber suitable for plywood. The results are being used by DFPA to establish a revision of the commercial standard for Douglas-fir plywood which would permit use of much of this rejected timber in the existing "D" grade of veneer now heavily used for interior sheathing.

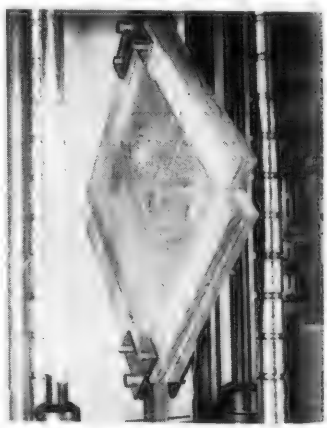
The proposed grade was developed from research involving both the gluing and strength of plywood made of it. The tests were designed to establish the strength properties of the sheathing grade of plywood made from 1/8 inch white pocket veneer. Three-ply and five-ply plywood made entirely of this veneer was tested to determine its bending strength and stiffness, shear strength, shock resistance, and nail-holding power.

The laboratory's research engineers worked out requirements that would allow any combination of three factors in the poorest 12-inch length of a 24-inch width in a sheet of veneer: 1) a knot or hole 1 to 2½ inches in largest dimension; 2) light white pocket in one-half the 24-inch width; and 3) heavy white pocket on one-quarter of that width.

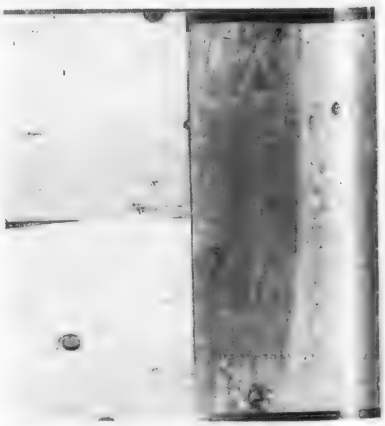
Tests showed that interior-type plywood containing white pocket veneers can meet glue bond requirements of the commercial standard when made with any of several hot-press protein-blend glues, extended phenol resin glue, and a cold-press blood glue. The cold-press soybean glue was inadequate, however. The high drying temperatures used in veneer driers kill the fungus that causes the white pocket.

It has been estimated that adoption of the revised "D" grade of veneer for interior sheathing plywood will make it possible to utilize up to one-half of all timber containing white pocket. Of the remaining 50 per cent, industry sources believe that three-fourths can ultimately be used with further research into its strength and gluing characteristics.

The Douglas Fir Plywood Assoc. is cooperating with the federal laboratory on further research aimed at establishing another grade, lower than the presently proposed grade but suitable for some of the uses now made of interior sheathing plywood, such as wall sheathing and containers.

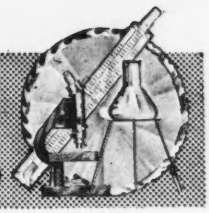


Tests on large panels, made for the first time, may become the basis for ASTM standards.



Acceptable combinations of white pocket and knots.

Abstracting the Literature



Fire Protection

Fire Retardants For Wood. D. C. Tibbett, Building Note No. 33, Div. of Building Research, National Research Council, Ottawa, Canada, January 1958, 8 pp. free.

A discussion of flame-retardant coatings and of impregnation treatment of wood. Methods of impregnation, chemicals used and effect of treatment in terms of permanence, strength, deterioration, etc. are included. [BRI Abstracts, Oct. 1958]

National Fire Codes. National Fire Protection Association, 60 Batterymarch St., Boston 10, Mass., 1958, 6 Volumes, 4,700 pp., $36.00. Individual volumes, $6.00 each.

A compilation of 168 separate fire safety standards. The six volumes by title are: "Flammable Liquids and Gases," "Combustible Solids, Dusts, Chemicals and Explosives," "Building Construction and Equipment," "Extinguishing Equipment," "Electrical," "Transportation and Misc." 41 new or revised fire safety standards are included. [BRI Abstracts, Oct. 1958]

Naval Stores

Barnes, Ellis O., and Taylor, Malcolm L. The naval stores and tall oil industries. *Tappi* 41, no. 8: 16A, 18A, 20A, 22A (Aug., 1958).

The production of rosin and turpentine by the naval stores and by the tall oil industries is compared. The production of oleoresin and its processing into gum turpentine and gum rosin, and into wood turpentine and wood rosin, in the naval stores industries are described. In 1957 production by these industries amounted to: 110,000 tons of gum rosin, 7.5 million gallons of gum turpentine, 350,000 tons of wood rosin, and 9.5 million gallons of wood turpentine. The process used by the tall oil industry is outlined in detail; in 1957 production of tall oil rosin amounted to about 50,000 tons and production of sulfate turpentine about 17 million gallons. [Bul. Pap. Chem. V. 29, No. 3]

Moisture Measurement

Kajanne, Paavo, and Hollming, Aarne. On moisture determination in wood chips using gamma ray scattering. *Paperi ja Puu* 40, no. 4a: 153–7 (Special number, April, 1958). [In English; Finnish summary]

Wood chips placed in thin cylindrical plywood containers of different diameters were irradiated with x-rays from a cobalt-60 source, and the scattered quanta were measured with a scintillation counter connected to a discriminating scaler. When measured at angles of 30–60° relative to the line of radiation penetration, the scattering was found to be a linear function of the moisture percentage of the chips (on a dry-wood basis). The accuracy of this method, which is based on the Compton effect, was within ± 5% absolute for all samples and within ± 1% for the majority of the samples tested. [Bul. Pap. Chem. V, 28, No. 11]

Waste Utilization

G.D.L. Utilization of branchwood. *Wochbl. Papierfabrik.* 86, no. 13: 595–7 (July 15, 1958). [In German]

Except for the totally resinified dark brown to black core, branchwood furnishes good papermaking fibers of high toughness which are suitable for the manufacture of high-strength wrapping papers, glazed and marbled packaging papers, hardboard, shoeboard, container board, trunkboard, and other board grades of high wear resistance and elasticity. Various machines for the separation and processing of branchwood, knots, splinters, and related wood wastes are mentioned, such as the Kink-Kreis branchwood separator and the Bezner wood splitter for separating the core from the useful fibers. Kollergangs for the fiberization of branchwood and other screen rejects must have heavy runners and should be operated at relatively high consistency, but not too dry, possibly with admixture of waste paper. They can be followed by hollander beaters and knot catchers, or by Nacke refiners and centrifugal screens. [Bul. Pap. Chem. V. 29, No. 2]

Logging

Biggar, J. C. Wheeled-tractor skidding and slashing of tree lengths. *Pulp Paper Mag. Can.* 59, no. 4: 229–30, 232, 234, 236, 238, 240, 242, 244, 246 (April, 1958); *cf.* B.I.P.C. 27: 137.

Changes, developments, and progress made since 1955 as a result of experience in the wheeled skidding of tree-length logs are reported. Much of the improvement reported in the application of the tree-length wheeled skid to the slasher operating pattern is attributed to the separation of the felling from subsequent phases of the operation. Modifications and improvements to be applied to 1958 operations are outlined. [Bul. Pap. Chem. V. 28, No. 12]

Log Bundling

Anon. Unique bundling system. *Pulp & Paper* 32, no. 2: 126–8 (Feb., 1958).

The former method of handling bundle-rafted logs at the West Linn, Ore. mill of Crown Zellerbach involved removing the straps from the bundles while the logs were still in the pond and "pike-poling" the logs into the log haul for delivery to the mill. The process was slow and created a difficult sinker problem. The problem was solved by the installation of a bundle-handling system: A driven propeller in the water creates a current which carries the bundles into a log well beneath an overhead traveling crane. Slings are attached about the bundle, and a crane lifts it above the log-receiving deck. The bundle strapping is removed, and the crane deposits the logs on a transfer section which automatically delivers the loose logs to a conveyor connecting directly with the mill. [Bul. Pap. Chem. V. 28, No. 10]

Wood Structure

Jazewitsch, W. von, Bettag, G., and Siebenlist, H. A new electric recording instrument for the measurement of annual ring width. *Holz Roh- u. Werkstoff* 15, no. 6: 241–4 (June, 1957). [In German; English summary]

A modification of Eklund's instrument (I) for measuring annual rings is described and illustrated. It automatically records the measured values and plots them on semi-logarithmic paper. In contrast to (I), the microscopic tube is movable over the resting object. [Bul. Pap. Chem. V. 28, No. 11]

Chemical Utilization

Anon. Fine chemical from fir bark. *Chem. Eng. News* 36, no. 7: 58 (Feb. 17, 1958).

An economical process for the large-scale production of quercetin from Douglas-fir bark has been developed by Weyerhaeuser Timber Co. The process involves the mechanical refining of the bark to yield cork flakes, which are then extracted with hot water to yield dihydroquercetin and tannins in solution. Air oxidation then dehydrogenates the dihydro derivative to quercetin. This is recoverable in purities of over 95% by cooling and filtering the solution. Quercetin finds applications in antioxidants, chemical syntheses, and pharmaceuticals. [Bul. Pap. Chem. V. 28, No. 10]

The preparation of abstracts from the world literature is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts used in the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles. Copies or additional information can not be supplied by FPRS or the abstract journal.

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin, by the Institute of Paper Chemistry.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL, published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England.

YOUR'S FREE . . . FOR SIGNING-UP JUST ONE NEW MEMBER!

Your choice of any FPRS Annual Proceedings for the years 1947 through 1951. These beautiful cloth-bound volumes will make a fine addition to your library. They represent the choice papers presented at FPRS' National Meetings each year. Your Proceedings will be sent to you postpaid anywhere in the world. Help us to get one or more new voting, associate, or supporting members and complete your library soon.

. . . And There's a Bonus for the New Member as Well!

WHEN YOU JOIN FPRS for calendar year 1959 as a *new* member you will receive an *extra* bonus in addition to the regular Society benefits. You, too, may take your choice of any of the above cloth-bound Annual Proceedings for your library.

One of the best ways to keep abreast of the newest and latest in wood technology is by joining FPRS. Just one good idea put to practice in your organization may return your modest membership cost many times. Mail your application *today* and start getting—

1) The outstanding monthly FOREST PRODUCTS JOURNAL.
2) Personalized service on your technical questions.
3) Important contacts with wood experts.
4) Notice of FPRS meetings from coast to coast.
5) And other benefits.

APPLICATION FOR MEMBERSHIP

1959 FOREST PRODUCTS RESEARCH SOCIETY 1959

ADDRESS OF THE EXECUTIVE SECRETARY
417 NORTH WALNUT STREET, MADISON 5, WISCONSIN

(DATE)

TO THE EXECUTIVE BOARD:

I hereby make application for

- ☐ Supporting Membership ($100)
- ☐ Voting Membership ($15)
- ☐ Associate Membership ($15)

} in the Forest Products Research Society, including regular publications of the Society. CHECK ONE (Qualifications defined on reverse of this sheet)

Note: Of $15 or $100 membership, $11.25 is paid for a one year subscription to the FOREST PRODUCTS JOURNAL.

(SIGNATURE)

Please provide *all* of the following information. The Executive Board cannot act on incomplete applications.

YOUR NAME _____
(PRINT OR TYPE)

COMPANY NAME _____

MAILING ADDRESS _____
(STREET)

_____
(CITY) (STATE OR PROVINCE)

NATURE OF BUSINESS _____

APPLICANT'S TITLE OR OCCUPATION _____

NOTE: New Member: Please Check Which Issue You Want FREE for Joining Now:

- ☐ Vol. I 1947 Proceedings,
- ☐ Vol. II 1948 Proceedings,
- ☐ Vol. III 1949 Proceedings,
- ☐ Vol. IV 1950 Proceedings,
- ☐ Vol. V 1951 Proceedings,

NOTE: Regular FPRS Member: Check Which Issue You Want FREE:

- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

NAME: _____

ADDRESS: _____

NOTE: THIS OFFER DOES *NOT* APPLY TO *STUDENT* MEMBERSHIPS.

Take Your Choice of FPRS Proceedings for Signing-Up One New Member

1947—Vol. 1—UTILIZATION, ENGINEERING, PRESERVATION, SEASONING. 25 papers, 344 pp.

Articles cover: whole wood fiber manufacture; lignin chemistry; processing pine gum; paper and plastic overlays for veneer and plywood; integrated utilization; trends in logging; pulpwood logging developments in eastern Canada; building codes in postwar wood construction; engineering problems in prefabricated homes; postwar packaging field; functional furniture; postwar woodworking glues; metal to wood bonding; high frequency in woodworking; wood finishing; the use of car treated lumber; fence posts; an untapped market for the wood preserver; acid-proofing of wood; the artificial seasoning of wood in vapor of organic chemicals; kiln design; tungsten carbide developments; and tight cooperage plywood. **Regular price $6.00**

1948—Vol. II—UTILIZATION, FIBER PRODUCTS, BARKING, FINISHES, MACHINERY, R. F. HEATING. 50 papers, 500 pp.

Articles cover: economics of wood-waste utilization; losses in Redwood logging; small log gang sawmill; utilization of low-grade hardwood lumber; wood-distillation industry; sawdust carbonization; animal feeds from wood residue; small wood briquetting machine; special machines for utilization of waste slabs for glued core stock; interior trim from wood waste; wood-fiber production with revolving disk mills; effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-Fir; small hydraulic log barker; mechanical methods of bark removal; studies on the chemical composition of bark and its utilization for structural boards; research in industry laboratories; history of furniture finishes; finishes resistant to alcohols and acids; low-bake synthetic finishes; simple testing methods for finishers; planning floor space for woodworking equipment; maintenance and operating practice for tungsten carbide tools. **Regular price $8.00**

1949—Vol. III—RAW MATERIAL, FURNITURE, PLYWOOD, UTILIZATION, GLUES, SEASONING. 55 papers, 607 pp.

Articles cover: more wood per acre; integrated wood utilization at Crossett; harvesting sawlogs; portable wood chippers; wood fibers from veneer waste; small permanent-type sawmills in better forest utilization; pulpwood handling in the Lake States; tropical wood research for the furniture industry; effect of plywood glue lines on the accuracy of moisture-meter indications; No. 3 common Northern hardwood lumber for mechanized processing into glued products; cut stock from western softwoods; assembly material in furniture manufacture; supplementing wood with metal in furniture manufacturing; extending hot press urea resin with wheat and rye flour; furniture finishes; lumber core panels; rotary veneer cutting; molding plywood; insert-point circular headsaws; ills besetting the furniture industry; utilization of Redwood bark; utilization of waste sulfite liquor in concrete; semichemical pulping; dry-formed boards bonded with resins; wood, plywood and hardboard; compreg-resin-treated densified wood; wood preservatives; wood boring beetles; ignition temperatures of fireproofed wood, untreated sound wood, and untreated decayed wood; wood waste disposal and air pollution control in the Los Angeles area; pulp mill pollution; chemical composition of Ponderosa and Sugar Pine barks; lumber recovery from Douglas Fir logs in British Columbia; resin adhesives; development of working stresses for stress-grade lumber; design and performance of laminated wood trusses; glued laminated wood; glued laminated Wej-weld frames; radio frequency heating. **Regular price $8.00**

1950—Vol. IV—MILLING, CONTAINERS, QUALITY CONTROL, PLYWOOD. 45 papers, 506 pp.

Articles cover: quality of second growth Douglas Fir; grading problems; quality control and the improved seasoning processes of the Redwood industry; saw teeth in action; lumber research to meet modern competition; hardwood log grading; recent developments in wirebound containers; method of utilizing and fabricating waste lumber; tests of strapped and lightweight lettuce crates; recent developments in containers; papermaking fibrous raw materials; utilization of low-grade hardwoods and softwoods; relation between wood and pulp properties; power vs. hand falling and bucking in logging operations; handling pulpwood; quality control in sawmill operations; hardwood plywood quality control; quality control in furniture production; defect detection equipment; non-destructive testing. **Regular price $8.00 Now $2.50**

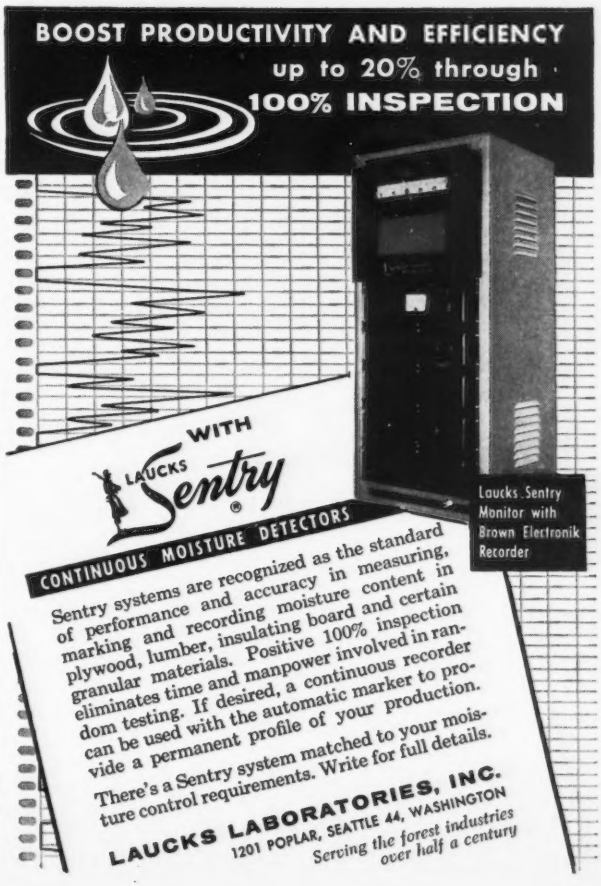
1951—Vol. V—MILLING, MACHINING, PRESERVATION, UTILIZATION, GLUES, KILN DRYING. 51 papers, 400 pp.

Articles cover: circular sawmills in the Tennessee Valley region; quality control in lumber manufacture; gangsaws in the manufacture of southern pine lumber; tropical hardwood production; logging and military equipment availability; defense and the availability of woodworking equipment; the importance of wood in the mobilization program; mobilization requirements for technical men in the woodworking industry; lumber conservation in military procurement and container design; military requirements for wood in packaging; wood requirements for specialized military uses; the place of small business in the military procurement program; marine laminating; selecting White Oak for bending lumber; machinability studies; carbide cutting tools in the wood industry; carbides; fire retardant treated lumber; wood preservation with particular reference to creosote; what the furniture industry expects from college-trained men; the scope and objectives of college training; graduate training in forest products technology. **Regular price $10.00**

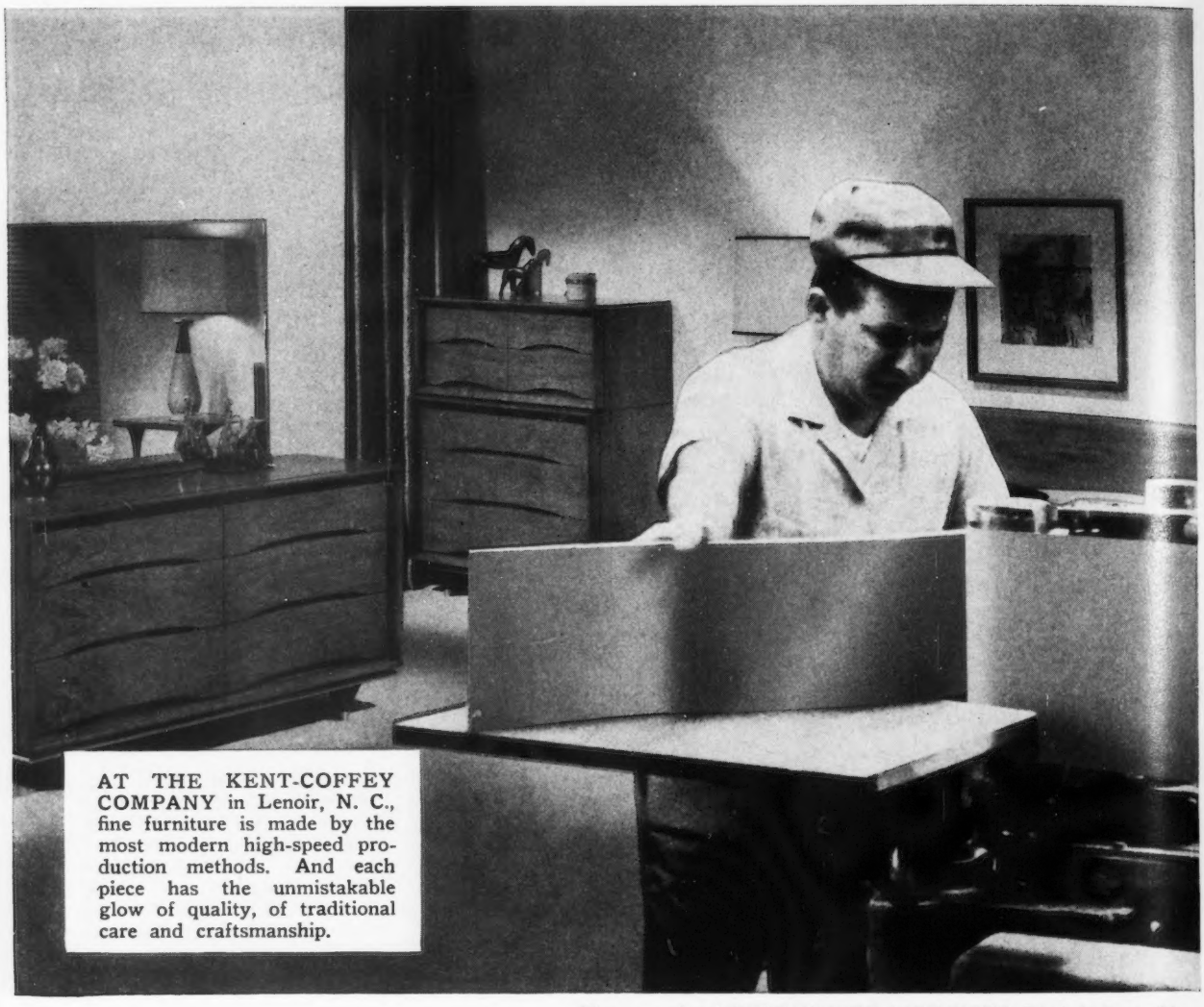
Index to Advertisers

	Page
Behr–Manning Co.	4th cover
Borden Chemical Co.	3-A
Buss Machine Works	2nd cover
Greenlee Bros. & Co.	2-A
Koppers Company, Inc.	13-A
Laucks Laboratories, Inc.	3rd cover
Mill Equipment, Inc.	3rd cover
G. Siempelkamp & Co.	14-A
Wilco Machine Works	12-A
1959 National Meeting	4-A

SELECTRIC®
sets the pace
in sawyer-operated setworks systems.
FROM 2 TO 30 H. P.
Write for complete information on the system engineered for your production requirements.
• Greater Sawing Accuracy
• Improved Grade Recovery
• Increased Production
• Lower Operating Costs
• Reduced Maintenance Costs
MILL EQUIPMENT INC.
5219 First Ave. South
Seattle 8, Wash.


BOOST PRODUCTIVITY AND EFFICIENCY
up to 20% through
100% INSPECTION
WITH
LAUCKS Sentry
CONTINUOUS MOISTURE DETECTORS
Laucks Sentry Monitor with Brown Electronik Recorder
Sentry systems are recognized as the standard of performance and accuracy in measuring, marking and recording moisture content in plywood, lumber, insulating board and certain granular materials. Positive 100% inspection eliminates time and manpower involved in random testing. If desired, a continuous recorder can be used with the automatic marker to provide a permanent profile of your production.
There's a Sentry system matched to your moisture control requirements. Write for full details.
LAUCKS LABORATORIES, INC.
1201 POPLAR, SEATTLE 44, WASHINGTON
Serving the forest industries over half a century

PARTNERS IN PROGRESS AND LEADERSHIP...



AT THE KENT-COFFEY COMPANY in Lenoir, N. C., fine furniture is made by the most modern high-speed production methods. And each piece has the unmistakable glow of quality, of traditional care and craftsmanship.

The use of a 4/0 RESINIZED METALITE Cloth belt on this edge sander produces a fine finish on serpentine drawer fronts.

METALITE® helps make fine furniture

Finer furniture is being made faster these days . . . due to the efficient coated abrasives developed by the Behr-Manning research laboratories and the improvements contributed by "Abrasive Tech."

If you have a specific sanding problem, or are interested in a detailed plant survey with recommendations how to increase production and lower costs — contact your nearest Behr-Manning office or write direct to Dept. FP-3.

The Sign of the Bear means a better product . . . and faster production.

WE RECOMMEND
How to use coated abrasives to cut costs . . . improve production, shown in the new 426-page book
COATED ABRASIVES
MODERN TOOL OF INDUSTRY
At bookstores or McGraw-Hill, N. Y.

BEHR-MANNING CO.
TROY, NEW YORK
A DIVISION OF NORTON COMPANY

BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes
NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electrochemicals
In Canada: Behr-Manning (Canada) Ltd., Brantford. For Export: Norton Behr-Manning Overseas Inc., Troy, N. Y., U.S.A.